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**COMBAT RATION
ADVANCED MANUFACTURING
TECHNOLOGY DEMONSTRATION
(CRAMTD)**

**"Survey Available Computer Software for Automated
Production Planning and Inventory Control, and
Software and Hardware for Data Logging and
Monitoring Shop Floor Activities"
Short Term Project #5**

**FINAL TECHNICAL REPORT
STP Results and Accomplishments (March 1991 through August 1992)
Report No. CRAMTD STP #5 - FTR 3.0
CDRL Sequence A004
August 1993**

**CRAMTD CONTRACT NO. DLA900-88-D-0383
CLIN 0004**

**Sponsored by:
DEFENSE LOGISTICS AGENCY
Cameron Station
Alexandria, VA 22304-6145**

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94-31082



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94 9 28 1 3 1

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE August 1993		3. REPORT TYPE AND DATES COVERED Final Mar 1991 - Aug 1992	
4. TITLE AND SUBTITLE Survey Available Computer Software for Automated Production Planning and Inventory Control, and Software and Hardware for Data Logging and Monitoring Shop Floor Activities				5. FUNDING NUMBERS C-DLA900-88D-0383 PE-78011s PR-88003	
6. AUTHOR(S) M.A. Jafari, T.O. Boucher, E.A. Elsayed					
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Rutgers, The State University of New Jersey The Center for Advanced Food Technology Cook College NJ Agricultural Experiment Station New Brunswick, NJ 08903				8. PERFORMING ORGANIZATION REPORT NUMBER FTR 3.0	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Defense Logistics Agency Cameron Station Alexandria, VA 22304-6100				10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES					
12a. DISTRIBUTION/AVAILABILITY STATEMENT				12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) Computer Integrated Manufacturing requires integration of production processes, information systems, and cost information. This Project surveyed available computer software for automated production planning and inventory control as well as computer software and hardware for data logging and monitoring shop floor activities. A baseline of vendor software/hardware applicable to Combat Ration Advanced Manufacturing Technology Demonstration (CRAMTD) was established. Working with other CRAMTD project teams, the computer network for the Demonstration Plant was defined. Two levels of networking are required: a low level network including PLCs and computers that run process control software, and a high level network for computers communicating with the database and planning/management functions. The process control computers link the networks. Commercially available software was recommended for process control. A customized database using a commercial database management system was selected for planning and management functions. Implementation of the selected software/hardware is underway.					
14. SUBJECT TERMS Production Planning, Inventory Control, Process Control, Data Logging, Shop Floor Monitoring				15. NUMBER OF PAGES 186	
				16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL		

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1.0 CRAMTD STP #5

Results and Accomplishments

1.1 Introduction and Background

Short Term Project #5, "Survey of Computer Hardware and Software for Automated Production Planning and Inventory Control, and for Data Logging and Monitoring Shop Floor Activities", was to conduct a survey of available computer software for automated production planning and inventory control as well as computer software and hardware for data logging and monitoring shop floor activities. The purpose of this survey was to find a baseline of vendor software and hardware applicable to the CRAMTD project. This activity was deemed necessary to pursue one of the goals of the CRAMTD program, which is to demonstrate Computer Integrated Manufacturing in the manufacture of combat rations.

Based on the information collected from other STPs, in particular STP #3 "Statistical Process Control" and STP #4 "CIM Architecture", and through a careful study of the processes involved, a set of requirements and desirable features were established for the subject software and hardware. These requirements and features were refined and modified during the course of this project as more information was collected. The requirements and features established in this way, provided a framework for evaluating vendor software and hardware identified during the survey. An effort was also made to acquire products on a trial basis for in-house examination. The results of all of these evaluations as well as the requirements and desirable features are documented in this final report.

The implementation of Computer Integrated Manufacturing (CIM) in combat rations manufacture requires the integration of manufacturing processes, information systems, and production cost information. The initial step in this process is the scheduling of deliveries of materials and production resources to maximize manufacturing process utilization while meeting delivery dates and minimizing inventory cost and spoilage of perishable materials. The collection of activities to achieve this purpose is referred to as production planning and inventory control. When a production plan is executed, the control over the plan is relegated to the shop floor level. On the shop floor, the main concerns are scheduling, process control, in-line inspection, in-process inventory control, throughput times, and recovery from system failure. In a CIM environment the execution of these functions in real time demands high speed data acquisition and data logging as well as appropriately designed software.

STP #5 was begun in early March 1991, based on the proposal submitted to the DLA on January 17, 1991, and completed in August 1992.

1.2 Accomplishments Summary

- Major software functions completed for the Enersyst oven PC interface. Implementation of the interface is being completed under the Implementation of Integrated Manufacturing STP #16.
- Specified the desirable characteristics and selection attributes for data acquisitions, monitoring, and control software and interfacing hardware and a technical report issued (TWP #46).
- Identified software requirements for production planning and control of the CRAMTD facility and a technical report issued (TWP #51).
- The survey of existing process control software was completed and a technical report (TWP #54) was issued. This document gives the hardware and networking requirements, interfacing, various functionality, and performance characteristics.
- Evaluated FIXDMACS process control software in hands-on experiments and issued an internal report describing the various features of the software.
- Evaluated ONSPEC process control software in hands-on experiments. An internal report was issued describing the experimental results and findings about this software package.
- Surveyed existing bar code technology and issued a technical report (TWP #57).
- Surveyed existing software on production planning and control and a technical report (TWP #64) was issued. This document described the various features of the existing production planning and inventory control that are applicable to batch and continuous type industries.
- Participated with the research team in the CIM Architecture (STP #4) in establishing the networking requirements for the CRAMTD Demonstration Facility.
- Participated with the research team in the Statistical Process Control (STP #3) in specifying the sensor data requirements for the CRAMTD manufacturing lines. Technical Working Paper (TWP #46) lists sensors and data acquisition devices.

1.3 Conclusions/Recommendations

In cooperation with the CRAMTD research team in STP#4, we defined the computer networking for the CRAMTD facility. Two levels of computer networking has been defined: low level computer networking including the PLCs and the computers that run the process control software, and the high level computer networking including the computers which communicate with the data base and planning/management functions. The computers running the process control software link the two networks. A schematic of the communication network, including some of the required computers, is shown in Figure 1, "Recommended CRAMTD CIM Architecture", Appendix 4.8.

As far as the process control software is concerned, we recommend the use of a commercially available software package. Our experience is that some of these software products are flexible enough to be tailored to the CRAMTD application by the CRAMTD research staff. For the planning and management functions supporting the data base, our conclusion is opposite in that the commercially available software products lack flexibility and open structure as required by our specifications. In STP #4, the prototyping of a data base which supports these functions started. As a result of STP #5, this work will continue on STP #16. Sections 3.2.2.1, 3.2.2.2, and 3.2.3 give more detailed discussions on these matters.

2.0 Program Management

There are two overlapping phases to this STP. These phases cover:

Phase I: Identification of requirements and desirable characteristics, and Industry survey.

Phase II: Evaluation of the existing software and hardware.

The objective of Phase I is to determine the requirements and desirable features for software in the areas of production planning and inventory control and for software and control hardware in the areas of data logging and shop floor monitoring. An industry survey is included to identify available computer software dealing with production planning and inventory control as well as computer software and control hardware dealing with data logging and monitoring shop floor activities.

The objective of Phase II is to evaluate the findings to ascertain the applicability of the computer software and control hardware that are available to the needs of CRAMTD.

3.0 Short Term Project Activities

3.1 STP Phase I Tasks

Phase I is the industry survey and identification of requirements and desirable characteristics. It consists of two tasks:

- Identification of desirable characteristics and requirements and preparation of preliminary software requirements specification.
- Conduct Industry Survey

3.1.1 Identification of Desirable Characteristics and Requirements (3.4.1)

In cooperation with the research teams in the Statistical Process Control Project (STP #3) and the CIM Architecture Project (STP #4), the desirable characteristics and requirements for process control and production control were identified and the findings documented in technical working paper "Desirable Characteristics and Selection Attributes for Data Acquisition, Monitoring, and Control Software and Interfacing Hardware", TWP #46 (attached as Appendix 4.1).

3.1.2 Conduct Industry Survey (3.4.2)

Industrial exhibitions and seminars were attended and different software and hardware vendors were contacted to prepare a comprehensive listing of the existing software and hardware. The findings were documented in technical reports "Process Control Software Review" TWP #54, "Introduction to Bar Coding" TWP #57, and "A Survey and Evaluation of Existing Production Planning and Control Software" TWP #64 (attached as Appendices 4.2, 4.3, 4.4 respectively).

3.2 STP Phase II Tasks

Phase II is the evaluation of the existing software and hardware. It consists of two tasks:

- Evaluation of Software and Hardware for Production Planning and Inventory Control
- Evaluation of Software and Hardware for Data Logging and Monitoring Shop Floor

3.2.1 Production Planning and Inventory Control (3.5.1)

In "Desirable Characteristics and Requirements for Production Planning and Control of CRAMTD Facility" TWP#51 (Appendix 4.5), we defined four classes of manufacturing related functions: business functions, manufacturing planning functions, product development functions, and manufacturing control functions. The class of business functions include accounting, sales forecasting, product costing, pricing and sales, order processing, and purchasing. The class of manufacturing planning functions include aggregate production planning, materials requirement planning, and production scheduling. The class of product development functions include formula management and maintenance. The class of manufacturing control functions include materials management and control, quality management, factory floor scheduling, shop floor control, and maintenance management. In TWP#51 we have given a comprehensive description of each of these functions together with their requirements.

In TWP#64 we gave an overview of software. We also tabulated different features of each software product. As we indicated in that report, all the surveyed software provide manufacturing planning and manufacturing control functions, with some also providing functionality in business and product development areas. Some of these software products run only on mid-range computers, and some run on both mid-range computers and PCs.

We considered flexibility and open structure as desirable characteristics for some of the functions to be provided with these software products. Flexibility of the software is required for handling both military and civilian type products. From our experience in STP #4, we know that military products require a different type of planning, inventory control, quality management, etc. The open structure of the software is required in order to facilitate the inclusion of specific purpose, application dependent functions. For instance, day-to-day scheduling of the operations is an application dependent function. The open structure requirement of the software allows the user to implement the appropriate scheduling routines. Our general observation is that the surveyed software products lack this open structure to a large extent. The use of any of these products for a given application requires some tailoring which is often done by the personnel of the software vendor or distributor. We concluded that the preliminary database with its supporting functions implemented on ORACLE during STP#4 provided the maximum open structure for use within CRAMTD Phase II.

3.2.2 Data Logging and Monitoring Shop Floor (3.5.2)

A comprehensive survey of existing software on process control and data acquisition and the related hardware was made. As far as the computer platform is concerned (TWP#54), these software can be divided into three classes: (1) the class of software which run only on micro-computers (PCs), (2) the class of software which run on mini-computers, (3) the class of software with different versions running on micro- or mini-computers. As far as the functionality is concerned, there are three main functions that many of the surveyed software are capable of performing. These functions are: data acquisition, basic statistical analysis, and control. Every

process control software package has software drivers to interface to different PLCs and I/O devices. The extent and the number of software drivers supported by a process control software product varies from one to another (see TWP#46). Some software products also provide tool kits so that the user can develop any desired driver. We have to say that, however, this task must be avoided as much as possible.

Some of the surveyed packages provide the user with a programming environment to develop the control logic for the system. As far as the statistical analysis is concerned, historical trending, different types of charts (e.g., Xbar chart, R-chart), and some very basic statistical computations (mean and variance) are provided by almost every process control software package. The extent to which these functions are implemented varies from one package to another.

Networking is also commonly supported by many of the process control software packages. The network protocol and the physical layer varies from one package to another. Another feature common to many of the existing process control software packages is that the data collected from the system in real time is stored in a temporary data base. Some of these packages provide an interface to spreadsheets, and others provide an interface to a relational data base such as ORACLE. Different process control software varies in scan rate, the rate by which input points are scanned and the collected data are stored. Generally speaking, however, the number of input points that can be handled by a single software package is in the order of hundreds and more. Some of the software packages also provide graphics facilities for the visual simulation of the system operation.

To summarize, we note that the surveyed software has many common features as described above. We found it quite difficult to rank this software in a general setting without any constraints for the other components of the system. Only when the other components of the system are somewhat specified, the distinction among these packages become more clear. For instance, given that we use Allen Bradley PLCs and ORACLE data base in a NOVELL network, we can easily eliminate some of these software packages. In the next section, we shall discuss the constraints that we find important.

3.2.2.1 Constraints

In TWP#51 we defined the tasks associated with the shop floor control function as those involving the real time data acquisition from sensors, data analysis, and control. In TWP#46 we presented a general architecture for data acquisition, monitoring, and process control. With respect to data acquisition, interface hardware or I/O devices are required. Interface hardware can be used in conjunction with PLCs or general purpose computers (e.g., PCs). If PCs are used, then the process control software could reside in the same or another PC. If PLCs are used, then there must be one or more general purpose computers (e.g., PCs) to run the process control software. In either case, the sensory data requirements must be known prior to the selection of the interface hardware. In TWP#46, we reported these requirements. One important interrelating factor between process control software and interfacing hardware is the driver software. This must be

emphasized in the selection process.

In the CRAMTD facility, the tray-pack line is controlled by an Allen Bradley PLC 5/12. The Enersyst Oven is controlled by an Allen Bradley PLC 5/10. The MRE pouch line is controlled by Allen Bradley PLC 2. These PLCs communicate through Data Highway (an Allen Bradley proprietary communication network). These constitute the lower level constraints that we have to consider in our selection process. As for the higher level constraints, we have the ORACLE data base selected in STP #4 to support the higher level functions. The CRAMTD research team in STP#4 and STP#5 also believed that PCs must be used in the various levels of the CRAMTD CIM hierarchy in order to emphasize the applicability of the CRAMTD technology for small and medium size producers. We consider this as another constraint in our selection process. In the remainder of our discussion, we shall refer to these constraints as "system constraints".

There are definitely more than a few existing process control software packages satisfying these system constraints. By glancing through TWP #54, one can easily find that, for example, FACTORY LINK, LABTECH CONTROL, EASYMAP, and FIXDMACS satisfy these constraints. There are also some software packages, e.g., ONSPEC, which do not have a link available to ORACLE, but instead, they provide some interface tool kit that can be used to develop the link.

Having narrowed down our list to those satisfying the system constraints, we looked for more constraints. In our discussion with the CRAMTD research team in STP#3, we realized that the selected software package must provide some basic statistical functions, such as historical trending, Xbar chart, and R-chart. Alarming was also considered an important function to have. These requirements were also stated for the quality management and control function in TWP#51. As we have indicated earlier, almost every process control package has these basic functions. However, the way the statistical functions are implemented could differ from one product to another. For instance, the number of windows that can be opened up simultaneously for historical trending and other functions varies from one product to another. Also the number of variables that can be included in one chart varies from one product to another. Unless these features are very crucial and are explicitly specified, one may not find the support for statistical analysis a decisive factor in the selection process as it is supported by many process control software products.

Some of these software products also have the facility (e.g., C libraries) to export data from their data base to user-defined software or third party software in order to do more complex statistical analysis. How simple it is to use this function very much depends on the particular software and cannot be discussed unless the software is tried. We consider such a facility an important constraint in our selection process.

Many of the process control software products support a graphics module from which a graphical simulation of the system can be developed. Such a graphical model could be crucial while operating the system as it can simulate the system operation in real time. Therefore, it is

considered a requirement. There are two versions of graphics that are commonly used in these software products: pixel graphics and object oriented graphics. For example, the DOS version of FIXDMACS uses pixel graphics. But the WINDOWS version of FIXDMACS or OS/2 version of ONSPEC use object oriented graphics. The object oriented graphics is much more practical and efficient, especially, when animation is used. The need for object oriented graphics was considered a constraint in our selection process.

As far as the operating system was concerned, we finally limited our attention to those software products that run on OS/2, DOS, or WINDOWS. This satisfies our requirement for PC based CIM system. The products running on WINDOWS or OS/2 generally use object oriented graphics. Some software products have versions for both OS/2 and DOS or WINDOWS.

In addition to these general constraints, there are some specific details that must be considered. For instance, the extent by which the various functions in a software product are implemented, the ease of using these functions, and the technical support provided by the software vendor are some important factors which must be considered. Unfortunately, these factors cannot be checked unless the software is tried. Therefore, we decided to have hands on experience with some of these products.

3.2.2.2 Final Evaluation and Recommendation

We decided to narrow down our hands on experiments to: ONSPEC and FIXDMACS. The justification for choosing these software products is as follows: (1) Both FIXDMACS and ONSPEC satisfy our general constraints described above, (2) Both FIXDMACS and ONSPEC are quite popular in industry and, in fact, several food manufacturers are currently using these two products. We acquired the two products on a trial basis for a period of about two months. Using the computer system (two PCs and an Allen Bradley PLC 5/12) that we had set up in our laboratory, we examined each software package. To make sure that our evaluation was complete and to answer some of our questions about the software, we invited an application engineer from each software vendor to meet with us. Following the completion of our evaluation, we issued an internal report for each of the two software packages ("Review of FIXDMACS v2.1 for DOS and FIXDMACS for Windows", Appendix 4.6 and "Review of ONSPEC 1000", Appendix 4.7).

We experienced some technical problems with ONSPEC (described in the report) which could not even be resolved by the technical staff from the software vendor. With the FIXDMACS, we did not have a major problem. We also found the technical staff of the software distributor quite knowledgeable about their product. At the same time, the two software packages had very comparable functions with some differences. One main difference is the way the two software packages handle the data storage throughout a network. We have discussed this in the two reports. It seems to us that the way FIXDMACS handles this function is superior to that of ONSPEC. Overall, we found FIXDMACS a better selection for our application.

3.2.3 Networking

In cooperation with the CRAMTD research team in STP#4, we defined the computer networking for the CRAMTD facility. Two levels of computer networking has been defined: low level computer networking including the PLCs and the computers that run the process control software, and the high level computer networking including the computers which communicate with the data base and planning/management functions. The computers running the process control software link the two networks. A schematic of the communication network, including some of the required computers, is shown in Figure 1, "Recommended CRAMTD CIM Architecture", Appendix 4.8.

Since the Allen Bradley PLCs are used for control of the CRAMTD lines, Allen Bradley Data Highway is selected as communication network for the low level. This network also connects to the computers which run FIXDMACS software. Two nodes are considered for FIXDMACS: a SCADA node which constitutes the core of the software performing data acquisition and control, and a view node for viewing different charts. The SCADA node is also used for the development of applications.

For the higher level communication, Ethernet cable has already been installed in the CRAMTD Facility. As far as the STPs 4 and 5 were concerned, the issue was to choose the protocol. Novell was selected due to its popularity and its compatibility with FIXDMACS and ORACLE data base.

4.0 Appendix

- 4.1 "Desirable Characteristics and Selection Attributes for Data Acquisition, Monitoring, and Control Software and Interfacing Software", Technical Working Paper, TWP #46.**
- 4.2 "Process Control Software Review", Technical Working Paper, TWP #54.**
- 4.3 "Introduction to Bar Coding", Technical Working Paper, TWP #57.**
- 4.4 "A Survey and Evaluation of Existing Production Planning and Control Software", Technical Working Paper, TWP #64.**
- 4.5 "Desirable Characteristics and Requirements for Production Planning and Control of CRAMTD Facility", Technical Working Paper, TWP #51.**
- 4.6 "Review of FIXDMACS v2.1 for DOS and FIXDMACS for Windows".**
- 4.7 "Review of ONSPEC 1000".**
- 4.8 Figure 1 "Recommended CRAMTD CIM Architecture".**

COMBAT RATION ADVANCED MANUFACTURING TECHNOLOGY DEMONSTRATION (CRAMTD)

**Desirable Characteristics and Selection
Attributes for Data Acquisition, Monitoring, and
Control Software and Interfacing Hardware
Technical Working Paper (TWP) 46**

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January 1992**

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"Desirable Characteristics and Selection
Attributes for Data Acquisition, Monitoring, and
Control Software and Interfacing Hardware"

Technical Working Paper (TWP) 46

M.B. Gursoy, M.A. Jafari and E.A.Elsayed

Abstract

This technical report describes the findings from (1) a survey of existing data acquisition and control hardware and software, and (2) the requirements and desirable characteristics of data acquisition and control hardware and software.

A data base application program is described which enables searches for sensor/interface/software combinations that fit user defined criteria. The data base presently contains data on 57 sensors, 24 interface boards, and 2 dataloggers.

Acknowledgment

We would like to thank the graduate students Mary Nirmal, Allison Veleber, and John Weber, and the undergraduate student Jeff Canavan for their assistance on developing the database and on preparing this report.

1.0 GENERAL

Purpose of the Technical Report

Section 3.4.2 of STP #5 Technical Proposal of contract DLA 900-88-D-0383 between Rutgers University and the Defense Logistics Agency requires the contractor to survey the industry for the existing data acquisition and control hardware and software. Section 3.4.1 of the same technical proposal requires the contractor to specify the requirements and desirable characteristics of data acquisition and control hardware and software. The purpose of this technical report is to describe the up to date findings in regard to the software and hardware requirements and the existing hardware and software. This is a working document and is subject to revision.

1.2 BACKGROUND

One of the major areas of computer automation in manufacturing systems is the actual control of the physical manufacturing process. Typically, the process parameters and products characteristics are continuously measured, monitored, and adjusted to ensure that both the product characteristics and the process parameters are within their specified target values. These three functions: measuring, monitoring, and adjusting process parameters and product characteristics are described below: *Measuring* the parameters of the manufacturing process and the characteristics of the manufactured product is achieved by using sensors and transducers. *Monitoring* of the processes and products is achieved by providing the sensor's data to a control system such as Statistical Process Control which includes control charts and limits. *Adjusting* the process parameter is an action performed based on the analysis of sensor's data by the monitoring system. In

other words, an adjustment of the process may deem appropriate at that time when values of the product characteristics or the process parameters are found to be deviating from their predetermined values.

A typical process control system consists of sensors and probes, computer hardware, interface between the computer and the sensors, and a process control software. Computer hardware such as Programmable Logic Controllers (PLCs) or general purpose computers are required for data acquisition, data analysis, and/or control. Interfacing hardware provides a communication link between the control hardware and sensors. The process control software is needed for data analysis, control and monitoring of the process. In section 2, we present a brief discussion on different architectures for control and monitoring.

The type of interfacing hardware and software depends on the type of sensors used in a given application. The selection of appropriate hardware and software is critical to the success of any application. This requires an identification of the appropriate parameters (or attributes) for each of the components involved in data acquisition, monitoring, and control of the desired processes. Here, we will discuss some of the attributes to be considered in the selection of each of these components. In this report we only focus on sensors, interfacing hardware between sensors and computers or PLCs, and process control software. We limit our presentation to components applicable to the CRAMTD facility, in particular the tray pack line as shown in Fig. 1. In section 3 we present a general discussion on the desirable attributes of sensors, interfacing hardware, and process control software.

To survey industry for the existing interfacing hardware and process control software requires the identification of the type of sensory devices to be used in the CRAMTD applications. This information is furnished to us by the CRAMTD group involved in STP #3. Then, in conjunction with the same group we started a survey of the industry. The survey is still underway. Due to the large variety of the existing hardware and software, we decided to develop a database for the collected information. In section 4, we describe the database structure and how to use it.

2. Architecture for Measuring, Monitoring, and Control of Processes

Figure 2 illustrates a schematic diagram of a measuring, monitoring and control loop for a typical manufacturing process. The hardware and software used in this loop will be described next.

Sensors are devices that convert physical quantities or measurements into electrical signals (voltage or current). For some sensors, the output signal is continuous or analog and for others it is digital. The analog signals must be converted into digital signals and then read by a computer (a general purpose computer or a PLC). Therefore, an A/D (analog to digital) conversion is required. Some sensors (e.g., thermocouples or RTDs) must have their output signal converted into standard level signals so that they can be read by A/D converters. The signal conditioning devices are used in this capacity for amplification, filtering, linearization, external excitation, and cold junction compensation.

The most common type of signal conditioning is amplification. Low level signals such as the thermocouple signals must be amplified to increase resolution. For the highest

possible resolution, the signal should be amplified so that the maximum voltage difference equals the maximum input range of the A/D converter. Another common signal conditioning function is linearization. Many signal conditioning modules are designed to match different types of thermocouples in order to amplify and linearize the signal. Signal conditioning could also be done for the purpose of external excitation as it is required by some sensors, e.g., RTDs.

To summarize, we note that a sensor's output analog signal must be converted and, in some cases, conditioned before it can be read by a computer (general purpose or PLC). There are different means of performing the signal conversion and conditioning: I/O boards and data loggers. Some sensors come with their own interfacing hardware, for instance, there are sensors which require data loggers. In the applications where the sensors are placed in a relatively far distance from computers, it is more appropriate to use data loggers as an alternative to running long sensor wires which may be expensive and the quality of sensory data may be compromised. A disadvantage of using data loggers is the slower data acquisition rate when compared to direct wiring to a PLC or a PC. Data loggers could communicate with computers through standard protocols such as RS-232.

As far as the control hardware is concerned, we can use PLCs or PCs. If a PLC is used for process control, then data acquisition is usually performed using the PLC itself. The PLC then passes the data to a general purpose computer (like a PC) where software for statistical process control and other types of analysis reside. It is possible to use a general purpose computer like a PC for process control, data acquisition, and statistical process control. PCs are quite useful in situations where data needs to be processed and

programming in a high level language is required. However, PCs are slow in applications where there are many input and output operations. On the other hand, PLCs are intended for harsh industrial environment with extremely high speeds for data acquisition and in performing logical functions which are required in process control.

The control loop is considered complete when the control hardware sends appropriate control commands generated by the control algorithms to the physical process. This requires an interfacing hardware including Digital to Analog (D/A) converters between the control hardware and the physical process. The discussion on this subject is beyond the scope of this report.

3. Discussion on Sensors, Interfacing Hardware, and Process Control Software

To be able to evaluate sensors and make a good selection, one must identify desirable attributes or characteristics of sensors to be used in a given application. For example in a given application, attributes such as measured quantity, measurement units, and measurement range are important to identify. The selection of sensors could further be restricted by the operating conditions for the sensor. For instance, temperature sensors could be used to measure the temperature of gravy in a kettle, the temperature inside the oven or the temperature of thawed beef. Hence, attributes like the ambient temperature and humidity, the sensors dimensions, weight, and its material play an important role in the sensor selection process.

Even if a sensor possesses all the desirable characteristics mentioned above, we still need to consider additional characteristics such as accuracy, response time, price, and so on. Moreover, we need to specify the computer interfacing requirements. In general, we

divide these characteristics into the following classes: General/Physical Characteristics, Performance Characteristics, Interfacing Requirements, Operating Condition Requirements, Characteristics relating to the Application Area, Characteristics relating to the Manufacturer, and other miscellaneous characteristics. The items in each of these classes are described in section 4.

For the interface hardware between sensory devices and computers, there are a number of desirable characteristics that need to be specified. We need to specify the number of I/O channels, sampling rate, resolution, range and accuracy, all of which affect the quality of the digitized signal. The number of analog channel inputs is specified for both single-ended and differential inputs on interface boards that have both types of inputs. Single-ended input channels are used when the sensor output signal is greater than 1V, the wire from the signal source to the interface hardware is short, and all inputs share a common ground signal, otherwise, differential channels are used.

Sampling rate determines how often conversions can take place. A faster sampling rate acquires more points in a given time and therefore can reconstruct the original signal better. Resolution is the number of bits that A/D converter uses to represent the analog signal. Range refers to the minimum and maximum voltage levels that the A/D converter can quantify. Multifunction A/D boards have different gains, thus, providing selectable ranges so that the board is configurable to handle a variety of different voltage levels. In general, we define two classes of attributes for the interface hardware: Interfacing Requirements and Manufacturer related attributes.

While the hardware used in data acquisition enables a computer to collect data and control a physical process, it is the software that provides the analysis of the data and the

instructions concerning the actions to take at any point in time. The software typically provides the operator interface, data reduction and analysis, control algorithms, and permanent data storage in the data base. To be able to collect data and download control commands, a software must have interfacing I/O drivers for various I/O devices. Therefore, compatible software and hardware can be selected if there is a related device driver.

A software will also require some hardware requirements, such as computer memory space, EGA, VGA card, math-coprocessor, hard drive capacity, and operator interface requirements. Most of the process control software have basic SQC/SPC functions such as histograms, trends, mean and standard deviation calculation, *X-bar* and R charts. Some software have more capacities. In addition to these functionalities, it is important to know data base interfacing of process control software. For instance, some process control software can be interfaced with commercial database systems, such as Oracle and dBase.

After the data is analyzed, various control algorithms can be implemented depending on the capabilities of the process control software. Most software include basic control functions such as PID, PD, ramp, on/off, feed back controls and basic mathematical functions. Some software may also provide logarithmic, exponential, trigonometric functions and some logical functions such as AND, OR and NOR. These all determine the control, mathematical, and logical functionalities of a process control software. To summarize we define the following classes of attributes for the process control software: Manufacturer related attributes, computer hardware/software requirements, Performance Characteristics, and process control capabilities.

4. Database Structure

Here we describe the structure for the data base application program developed as part of STP #5. The database is of relational type developed in dBase IV. It runs on an IBM PC/AT, PS/2, or compatibles, requiring DOS operating system and a minimum of 640K RAM and 40Meg hard disk.

There are three entities (sensor, interface hardware, and software) in the data base. Each entity has a number of attributes (or fields) which collectively describe that entity. Each field has a name and type which could be character, numeric, logical, or comment (memo). The database explores the logical relationship that exists between some of the fields of these entities. For instance, the output signal generated by a sensor must match with the input signal of the interface hardware to be used with that sensor. Such a relationship is used in the database to search for a combination of sensors and appropriate interface hardware. Also compatibility between software and hardware is explored in the database.

The major function of this application program is to search the database for information about the three entities that fit the criteria that the user defines. There is an input program which takes the user's input and assigns variables to the user-defined inquiries. There are several input menus that the user has to work with. The first input menu is to select either a station (e.g., filling station) or a range for a desired attribute (for instance, temperature range). If a station is selected, then the program itself would find the appropriate ranges for the attributes which will be defined in a subsequent menu. The second menu is for the selection of a desired production line (MRE pouch or Tray pack line). Presently, the database contains information only about the tray pack line. The

third menu is for the selection of a desired attribute (e.g., temperature) to be measured. The third menu calls another menu (called "branch menu") which provides the user with options for interfacing or other information. Based on the user's selection, another menu is displayed from which the user will choose the desired output format. All this information together with the variables that are defined by the input program are fed to an output program. This program performs the search and displays the information on the screen in a specified format.

In menus one and three, it is possible to specify no constraints for station and attribute. For example, if the user wants to get information about all the sensors which could be used in a given station, then in the first menu "station" and in the third menu "no constraint" option must be selected. If one selects "no constraint" option in the first and in the third menu, then most general search would be performed.

As described earlier, each entity has a number of fields or attributes. Next we will give the list of attributes for each of these entities. For each attribute, we give the name used in the database followed by a description. In addition to the classes of attributes described earlier, for each entity we also define an attribute class used internally by the database.

SENSOR ATTRIBUTES

Information for the internal use of the database :

- Sensorcode : Sequential numbering of each sensor as it is entered into the database.

Sensors with more than one application, e.g., pH and temperature measurement, are listed with the same sensor code.

- Mancode : Sequential numbering of each sensor manufacturer. If the company makes more than one sensor, the code is repeated.

General/Physical Characteristics

- Power : Voltage or frequency of power source running the sensor.
- Geometry : Dimensions (L x W x H)
- Material : Material used in manufacturing the sensor.
- Weight :Pounds or Kilograms.

Performance Characteristics

- Resptime : How long it takes for the sensor to respond to each action.
- Accuracy : Accuracy of sensor output.
- Calibrate : Is Calibration needed to enhance accuracy of the sensor?
- CalMethod : Description of Calibration method.
- Repeat : % Repeatability of sensor in two successive measurements

Manufacturer Related Information

- Model : Model name as given by the manufacturer.
- Serial : The manufacturer's serial number for identification of the sensor.
- Ordercode : Manufacturer number for ordering the product.
- Price : List price (including required options).

There are also manufacturer related fields for address and telephone number.

Attributes Related the Application Area

- Att : Attribute which the sensor measures (TEMP (Thermocouple, RTD), PH, MOISTURE, FLOW, SALT, FAT, VISCOSITY, AIR SPEED).
- Rlow : Low value of attribute measurement (e.g., 0°C, 0 PH, 0% salt, etc.).
- Rhi : High value of attribute measurement (e.g., 100°C, 14 PH, 99% salt, etc.).
- Units : Units of measurement (e.g., C, PH, %, CPS, etc.).

Operating Conditions Requirements

- Templow : Low value of ambient or operating temperature.
- Temphigh : High value of ambient or operating temperature.
- Humhigh : Highest allowable operating humidity.

Miscellaneous Attributes

- Controller : Controller type used with sensor or does it operate as a controller.
- Comments : Additional comments to further explain the sensor.
- Online : Can the sensor be used online?
- Offline : Can the sensor be used off line?

Interfacing Requirements

- Analoglow : Low value for an analog output.
- Analoghigh : High value for an analog output.

- Analogunit : Units of Analog output (e.g., mA, mV, V)
- Distributd : Can the sensor be used with a distributed versatile module?
- Digitalout : Output digital connection (e.g., RS-232).
- Datacode : Code for datalogger specific to the sensor.

MODULE/BOARD/DATALOGGER ATTRIBUTES

A. Module:

Information for the Internal Use of the DataBase

- Modcode : Sequential numbering of modules as they are entered into the database.

Manufacturer Related Information

- Modelnum : Manufacturer model number for the module.
- Modprice : Price for standard model as well as the price for options.

There are also attributes for manufacturer's name and address.

Interfacing Requirements

- Attribute : Signal attribute (e.g., mA, mV, V, RTD, Temp).
- Analoglow : Low value for analog signal (e.g., 0 mA, 0 mV, 0V, 0°C).
- Analoghigh : High value for analog signal (e.g., 20 mA, 100 mV, 10V, 100°C).
- Analogunit : Units for the analog signal (e.g., mA, V, mV).
- Distributd : Distributed Module?

- Boardlow : Low value for board output (e.g., 0V,-5V,-10 V).
- Boardhigh : High value for board output (e.g., 5V,10V).
- BoardUnit : Units of board output (e.g., V).
- ModSoftwar : Software used if module is distributed.

B. Board:

Information for the Internal use of the Database

- Boardcode : Numbering of each board as it is entered into the database.

Manufacturer Related Information

- Bmodel : Model Name or Model Number of the board.
- Bprice : Price of Board including options.

Additional information about the board's manufacturer address, and name is also included.

Interfacing Requirements

- Samprate : Sampling rate of board (number of scans per second).
- Gains : Gains provided by board.
- Boardlow : Low input (e.g., 0V,-5V,-10 V).
- Boardhigh : High input (e.g., 5V,10V).
- Boardunit : Input unit (e.g., V).

- Attribute : Attribute of Board input (e.g., Analog, RTD, Temp).
- Bcomputer : Type of computer to interface with the board.
- PLC_Inter : Can the board interface with PLCs?

C. Dataloggers:

Information for the Internal use of the Database

- Datacode : Numbering of each datalogger as it is entered into the database.

Manufacturer Related Information

- Datamodel : Datalogger model number used by its manufacturer.
- Dataprice : Datalogger price including options.

Interfacing Requirements

- Digitalout : Digital connection into the datalogger.
- PLC_Inter : Can the datalogger interface with PLC?
- Datarate : Datalogging rate.
- Inputdata : Any required inputs into the datalogger.
- Datacomp : Computer compatible with the datalogger.
- Dataout : Output connection into a computer or a PLC.
- Datalow : Low output value.
- Datahigh : High output value.

- Dataunit : Output value unit.

Software Attributes

Information for the internal use of the Database

- Softcode : Numbering of each package as it is entered into the database.

Manufacturer Related Information

- SFPackage : Package name.
- SFPrice : List Price including options.

Computer Hardware/Software Requirements

- Scomputer : Computer platform.
- Graphcard : Graphics Card requirements.
- Memory : Computer memory requirements (e.g., 640K RAM).
- Coproccss : Does it need a coprocessor (usually a math coprocessor)?
- EGA : Does it work with an EGA card?
- VGA : Does it work with a VGA card?
- Harddrive : Required hard drive capacity.
- Database : Database or Spreadsheet which can be used with this software.
- OPSystem : Operating system requirements (e.g., DOS, UNIX, OS/2).
- Mouse : Yes or No?

- Touchscreen : Yes or No?

Performance Characteristics

- Scanrate : Data scanning rate of the software.
- Alarmpts : Number of alarm points or levels.
- Num_Device : Number of hardware devices compatible with the software.
- Datain : Input connection to the computer (e.g., RS-232C)
- AB_Driver : Does the package have Allen Bradley drivers?
- Num_Colors : Number of colors offered.
- Num_Variab : Number of Variables that can be assigned.
- Datlograte : Rate at which the package takes in the information it scans (datalogging rate which the software stores the data it scans).
- Num_Models : Number of models or scenarios the package can handle.
- Networking : Can the Package be networked?
- Num_Vrs_Mo : Number of variables allowed in each model.

Process Control Capabilities

- SPC_Basic : Does it do Basic SPC functions (e.g., \bar{X} , R, Mean, Std. Dev)?
- SPC_Upgrad : Does it do Upgraded SPC functions (e.g., Cusum, Moving Average)?

How to Use The Database Application Program

Before using the program, it would be helpful to understand the basic functioning of the system. The first step is the user input. The user selects items that constrain, or filter a search through the database of sensors. The user selects from menus in the input program any items that are common to the group of sensors that are needed. Two general types of searches are accommodated by the output program that displays the information collected from the search. A Type A search is based upon the user's direct input of ranges and attributes for a sensor type. The second type, Type B, involves the user's choice of station and/or attribute.

To begin using the database system, a computer (its type was described earlier) that has dBase IV already installed is used. This program can be accessed by specifying the floppy drive that has the program on it when booting up the dBase. A list of the relational files and form designs will then be displayed along with the applications list. The application program itself is called 'IMPROVED'. Choose this item from the menu, and run the application.

Type A

1. Select 'USER RANGES', then enter a numerical range of attribute.
2. Select line constraint
3. Select attribute constraint
4. Select general type of Information required
5. Choose specific output format
6. View data
7. Press Esc once to return to previous menu to select other forms
or Esc twice to return to general information format menu to select

other output formats

8. Select 'Quit' and restart to begin another constraining search.

Type B

1. Select Station or "NO CONSTRAINT"

2. Select line constraint

3. Select Attribute or "NO CONSTRAINT"

4. Select general type of Information required

5. Choose specific output format

6. View data

7. Press Esc once to return to previous menu to select other forms or Esc twice to return to general information format menu to select other output formats

8. Select 'Quit' and restart to begin another constraining search.

After the necessary constraining information is entered, the output selection branching menu will be displayed. In the menu, the user can choose between two types of reports. The user can choose information from the menu by selecting either the general report forms for information concerning software, software working with PLC's, or a pricing summary, or for information forms for the sensors with boards or dataloggers. After a selection is made, a menu corresponding to the choice is displayed.

Output Menu Choices:

Interfacing

Software Form- Software specific data associated with constrained sensors

Datalogger Form - Data summary of constrained sensors with analog output

Board Form - Data summary of constrained sensors with digital output

Quit - Stop program to restart input of constraints Other Information

PLC Report - Information outline for Software with PLC compatibility

Price Report - Sensor, board and software prices

Operating System report - Outline of compatible operating systems

Quit - Stop program to restart input of constraints

Quit

NOTE: If no sensors are found in either Datalogger or Board Forms, then either one could be selected to get an output. This occurs if a sensor does not have the desired analog or digital output

Once in the forms, the user can search the forms by moving the cursor with the arrow keys to the different fields and pages. One important point is that in order to view information in a memo field, the user must press Ctrl-Home when over a 'MEMO' field that is currently in full Caps. If Memo is all in lower case, there is no additional information contained in that field. To escape from a memo field, the user has only to press Ctrl-End, which closes the memo field. To return to the output menu, the user must press Esc. This will return the user to the previous menu.

To choose another report, the new report title should be highlighted and entered. This cycle can continue for all of the reports. However, to get to the other menu of reports, the user must press Esc to get to the branching menu. From this menu, the other set of options can be chosen. If a new search is to be made with different constraining criteria, the user must choose 'QUIT' from the menu and restart the application.

Appendix I illustrates sample outputs from the database application program. As it is shown, there could be a number of different hardware and software interfaces for a given sensor.

Appendix II summarizes the data presently in the database for sensors and interface hardware. The data for the process control software will be included in a subsequent technical report.

Figure 1 : SPC Stations in Tray Pack Line

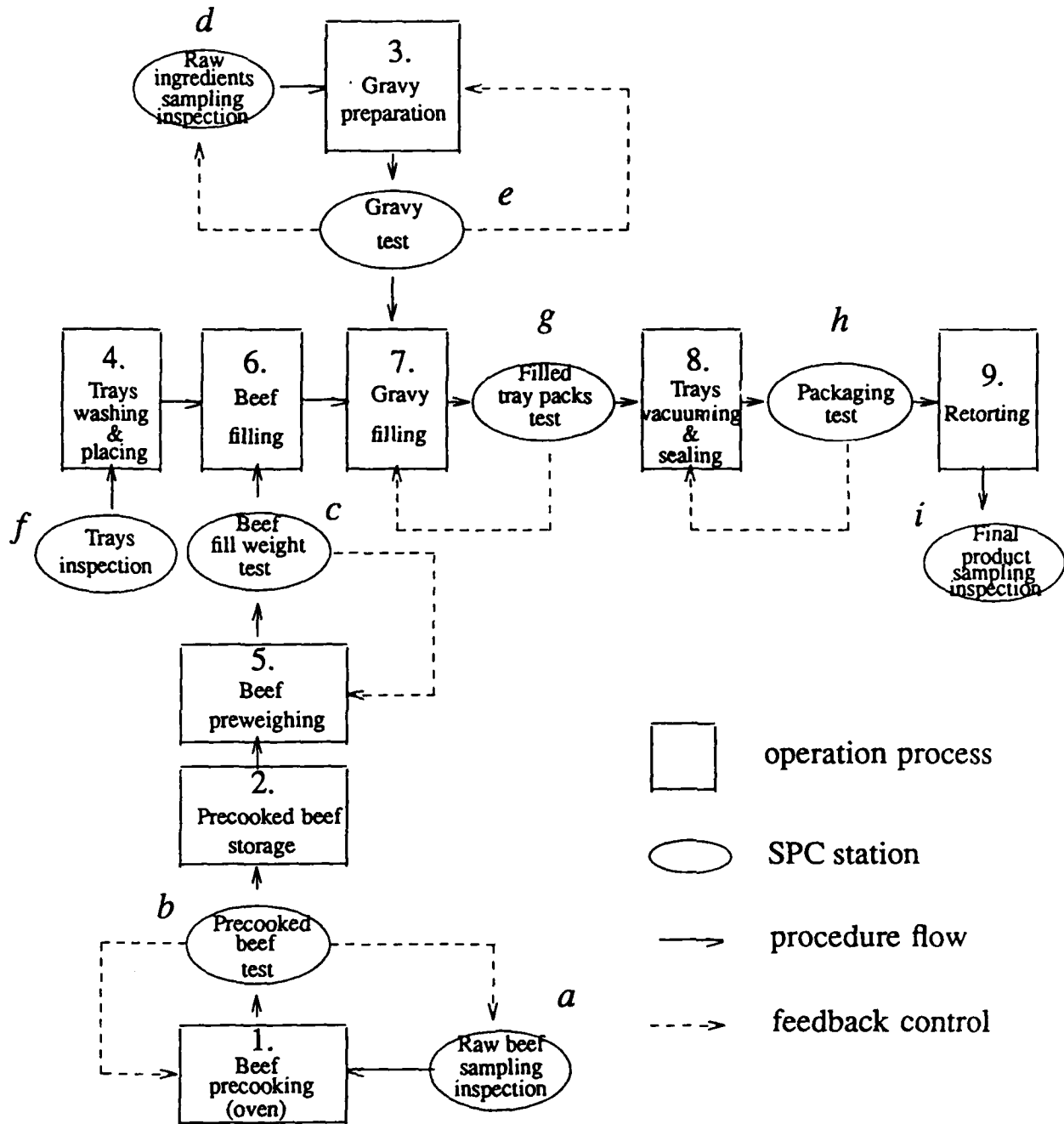
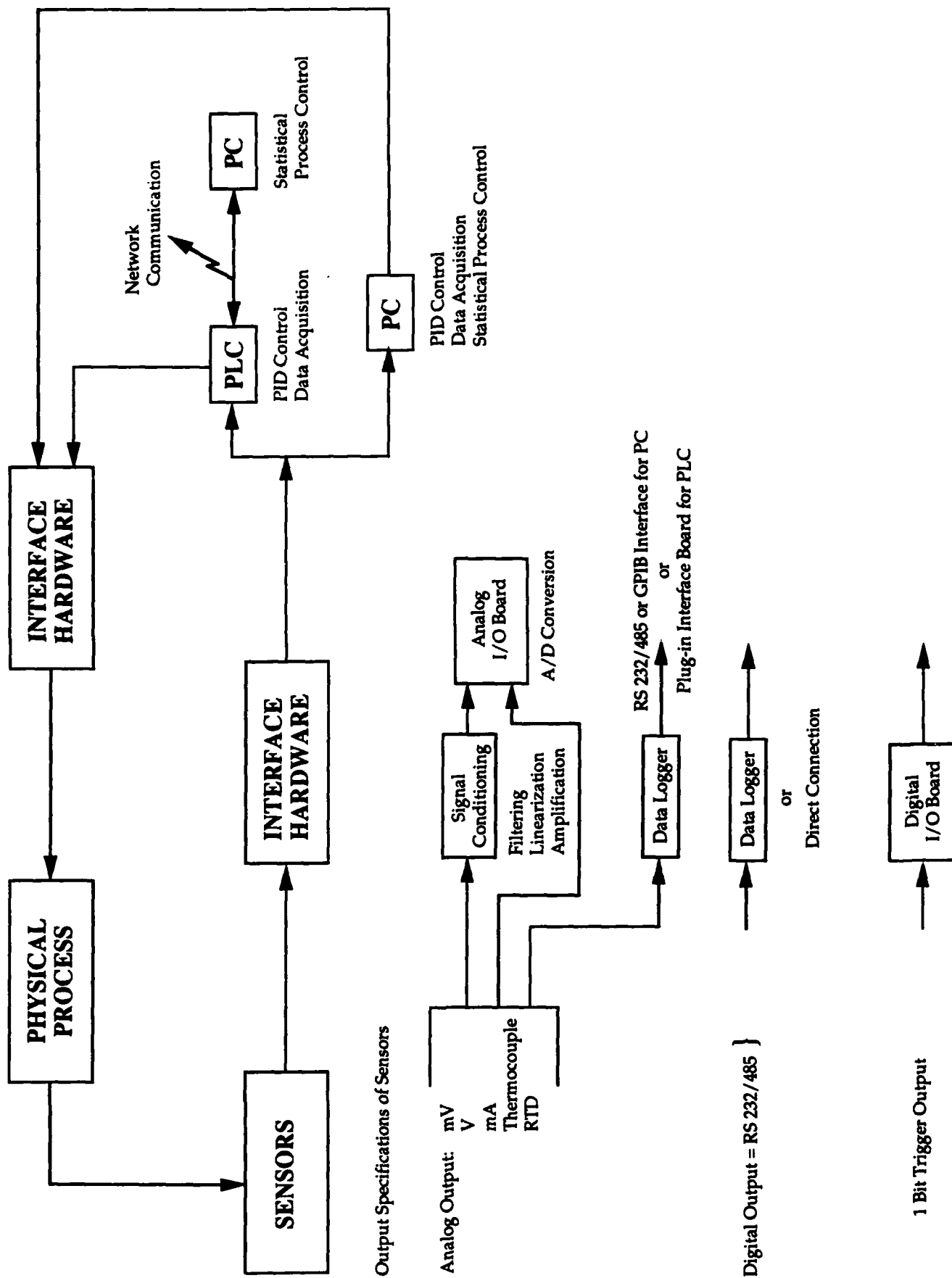


FIGURE 2 CONTROL AND MONITORING HARDWARE / SOFTWARE



Appendix 1

Sample Output from Database Application Program

All entry blocks have
the following format

SENSORS

INTERFACE

SOFTWARE

Sensor: Type
Manufacturer
Output: Range

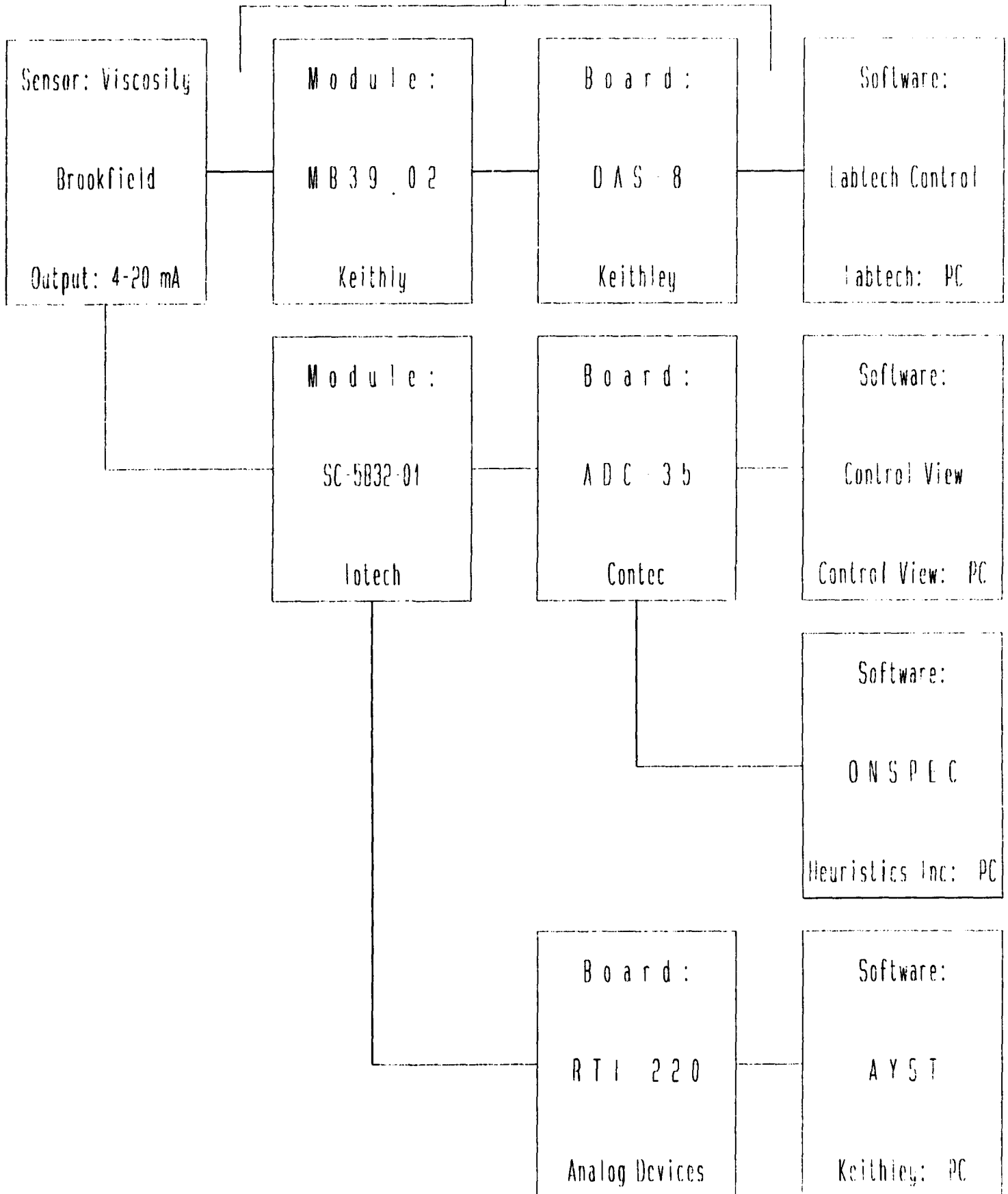
Interface Type:
Model
Manufacturer

Software:
Package Name
Manufacturer

SENSORS

INTERFACE

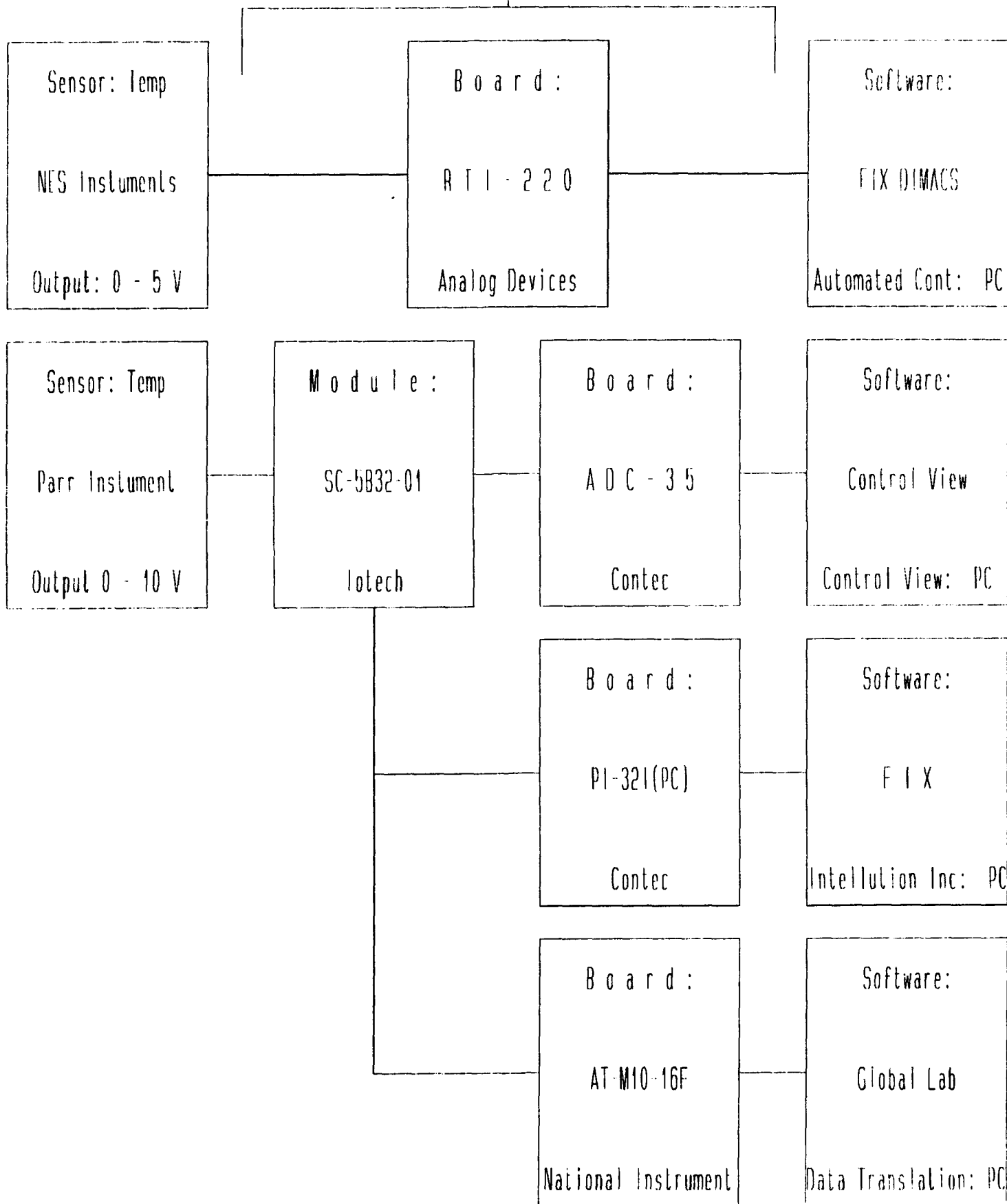
SOFTWARE



SENSORS

INTERFACE

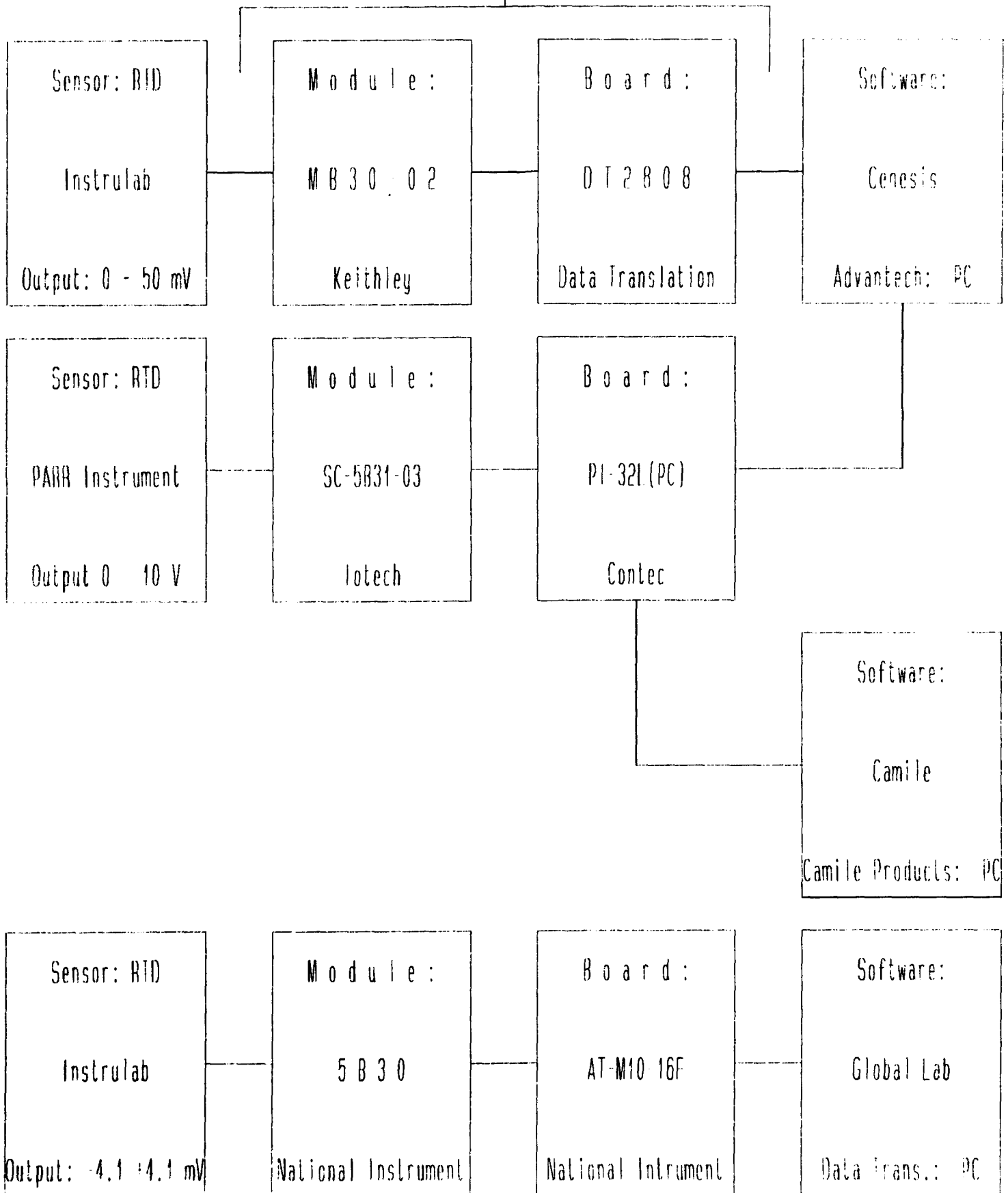
SOFTWARE

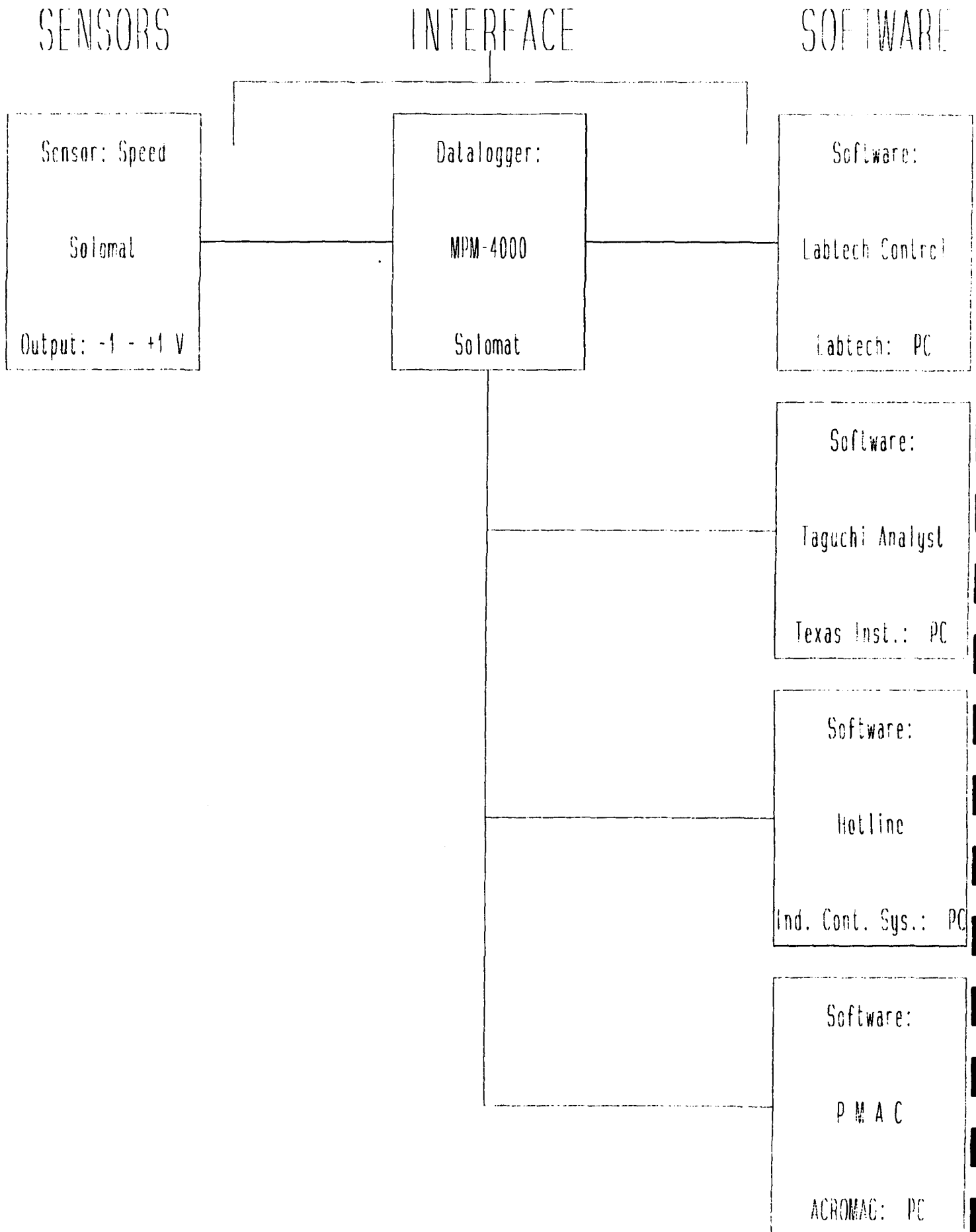


SENSORS

INTERFACE

SOFTWARE





SENSORS

INTERFACE

SOFTWARE

Sensor: Salt
Cargill, Inc
Output: RS-232



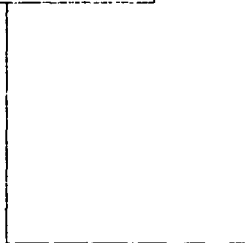
Software:
Autonet
Imagination: PC

Sensor: Salt
NORMAR CO.
Output: 4-20 mA

Module:
5 B 3 2
National Instrument

Board:
AT-M10-16F
National Instrument

Software:
Global Lab
Data Transl.: PC



Module:
SC-5B32-01
Iotech

Board:
PI-32L(PC)
Contec

Software:
CIMPROC
Data Int. Inc: PC

Sensor: Salt
AKZO Salt
Output: 0 10 V

Module:
SC-5B31-03
Iotech

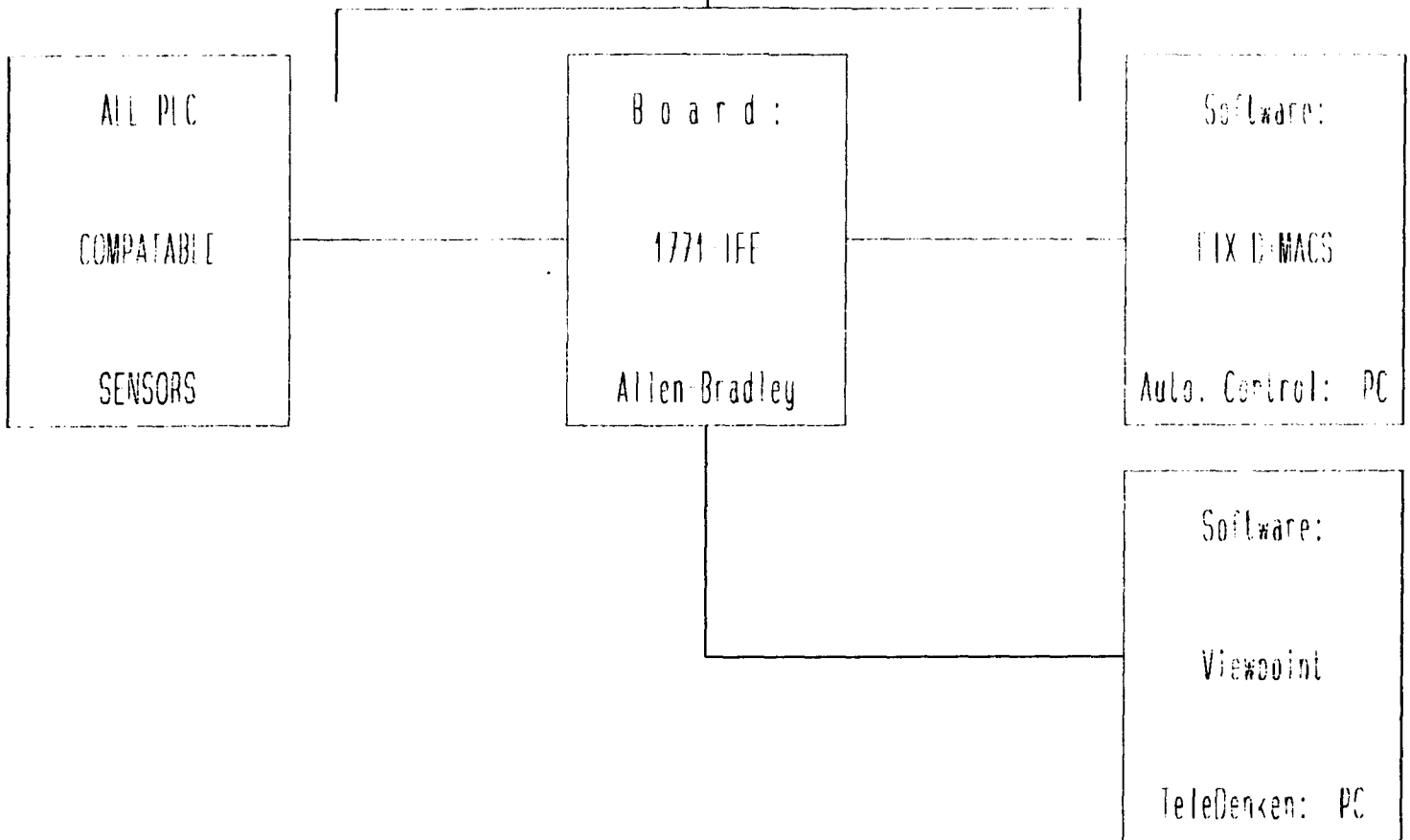
Board:
A D C 3 5
Contec

Software:
Control View
Control View: PC

SENSORS

INTERFACE

SOFTWARE



Appendix 2

Summary of Data
Presently in the Database
for Sensors and
Interface Hardware

Sensor Data

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Code	Sensor Name	Sensor Attribute	Read High	Read Low	Units
S001	M90B	TEMP	1000	-50.00	C
S002	M500 SERIES	TEMP	500	0.00	F
S003	1810	VISCOSITY	200000	0.10	CPS
S004	TT100	VISCOSITY	500000	10.00	CPS
S005	TT200	VISCOSITY	500000	10.00	CPS
S006	500E	SEE MEMO	0	0.00	
S007	450	SEE MEMO	86	36.00	%
S008	600T/L	SEE MEMO	86	36.00	%
S009	CT-90790-00:TYPE J	TEMP	1200	-210.00	C
S010	CT-90790-00:TYPE J	TEMP	1200	-210.00	C
S013	CD-90110-10	TEMP	121	-17.00	C
S014	CD-90110-15	TEMP	121	-17.00	C
S015	CD-90110-20	TEMP	120	-40.00	C
S016	CD-90110-25	TEMP	120	-40.00	C
S017	3312	TEMP	100	0.00	C
S018	4312	TEMP	400	-100.00	C
S019	SALTAN	SALT	99	0.01	%
S020	316-4A	FAT	50	0.00	%
S021	4202	RTD	660	-218.00	C
S022	4212A	RTD	660	-218.00	C
S023	4221	RTD	660	-218.00	C
S024	1100T	FLOW	30	0.00	FT/S
S025	1100L	FLOW	30	0.30	FT/S
S026	MPM2000	SEE MEMO	0	0.00	
S027	TDT-5768	TEMP	900	-200.00	C
S028	1671EB	TEMP/CONTR	0	0.00	
S029	1671	TEMP/CONTR	0	0.00	
S030	1180E RTD PROBE	RTD	600	0.00	C
S031	FOSS-LET MK II	FAT	98	0.00	%
S032	DICROMATT II	SALT	100	0.10	%
S033	BSP-901	MOISTURE	80	0.00	%
S034	MCP-1 IRIII	MOISTURE	99	0.00	%
S036	AE-4256	TEMP	750	0.00	C
S037	AE-4128	TEMP	50	0.00	C
S038	511PX/229MP	AIR SPEED	20000	300.00	FT/M
S039	103 AX AIR/GAS PT	TEMP	600	-190.00	C
S040	203 A AIR/GAS: ST	TEMP	600	-80.00	C
S041	327 TMX OPTICAL	PM	6000	40.00	RPM
S042	358RHX REMOTE	HUMIDITY	98	0.00	%RH
S043	BOSTWICK CON	VISCOSITY	0	0.00	
S044	RVDV-III RVH DIAL	VISCOSITY	40000000	100.00	CP
S046	BSP-4004	MOISTURE	80	0.00	%
S047	1168E THERMISTOR	TEMP	70	0.00	C
S048	SERIES 400	TEMP	100	0.00	C
S049	SERIES 800 INDUST	RTD	400	-100.00	C
S050	MG 711/D	FLOW	0	0.00	

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S051	ndf/USP	FLOW	0	0.00	
S052	SEE BROCHURE	FLOW	0	0.00	GPM
S053	1321F0 - CAST	FLOW	100	0.00	GPM
S054	874PH	PH	14	0.00	PH
S055	871A	PH	12	0.00	PH
S056	BT551	PH	14	0.00	PH
S057	BT557	PH	14	0.00	PH
S058	BT556	PH	14	0.00	PH
S059	BT553	PH	14	0.00	PH
S060	BT564	PH	14	0.00	PH
S061	4510	SEE MEMO	0	0.00	

NOTE: The Data on the next page can be related to the data on this and the previous page by the sensor codes. The data on the next page is a continuation of the data stored for each sensor. For some of the sensors, we did not receive data for the attributes listed on the next page. These sensors have been omitted from the next page.

Sensor Data (Cont)

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Sen. Code	Analog Low	Analog High	Analog Unit	Dist.	Digital Out
S001	0.0	0.0			
S002	0.0	0.0			
S003	4.0	20.0	mA	Y	RS-232C
S004	4.0	20.0	mA		RS-232C
S005	4.0	20.0	mA	Y	
S006	-1.0	1.0	V	Y	RS-232C
S007	0.0	0.0			RS-232C
S008	0.0	0.0			RS-232C
S009	-10.0	100.0	mV	Y	
S010	-10.0	100.0	mV	Y	
S011	0.0	0.0			
S012	0.0	0.0			
S013	0.0	0.0			
S014	0.0	0.0			
S015	0.0	0.0			
S016	0.0	0.0			
S017	-4.1	4.1	mV	Y	RS-232C
S018	-4.1	4.1	mV	Y	RS-232C
S019	4.0	20.0	mA	Y	RS-232C
S019	0.0	0.0	NONE	N	RS-232C
S020	0.0	0.0	NONE	N	RS-232C
S021	-4.1	4.1	mV	Y	RS-232C
S022	-4.1	4.1	mV	Y	RS-232C
S023	-4.1	4.1	mV	Y	RS-232C
S024	4.0	20.0	mA	Y	NONE
S025	4.0	20.0	mA	Y	NONE
S026	0.0	0.0	NONE	N	RS-232C
S027	0.0	5.0	V	Y	RS-232C
S028	0.0	10.0	V	Y	RS-232C
S029	0.0	10.0	V	Y	RS-232C
S030	0.0	10.0	V	Y	RS-232C
S031	0.0	0.0			RS-232C
S032	0.0	10.0	V	Y	RS-232C
S033	4.0	20.0	mA	Y	NONE
S034	4.0	20.0	mA	Y	NONE
S035	0.0	0.0			
S036	0.0	0.0			RS-232C
S037	0.0	0.0			RS-232C
S043	0.0	0.0			
S044	0.0	1.0	V		RS-232
S045	0.0	0.0			
S046	4.0	20.0	mA		RS-232
S051	4.0	20.0	mA		

Module Data

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Module Name	Attribute	Analog Low	Analog High	Analog Unit	Dist.
5B30	mV	-50.0	0.0	mV	N
5B30	mV	-100.0	100.0	mV	N
5B32	mA	0.0	20.0	mA	N
5B34	TEMP	-100.0	100.0	C	N
5B47	TEMP	-100.0	300.0	C	N
5B47	TEMP	-100.0	400.0	C	N
MB47-J-02	TEMP	-100.0	300.0	C	N
MB47-T-06	TEMP	-100.0	400.0	C	N
MB30-02	mV	-50.0	50.0	mV	N
MB30-03	mV	-100.0	100.0	mV	N
MB39-02	mA	-5.0	5.0	V	N
MB37-J	TEMP	-100.0	760.0	C	N
MB37-K	TEMP	-100.0	1350.0	C	N
MB34-01	RTD	-100.0	100.0	C	N
MB32-01	mA	4.0	20.0	mA	N
3B30	mV	-100.0	10.0	mV	N
3B12-01	mA	4.0	20.0	mA	N
3B14-01	RTD	-100.0	1.0	C	N
3B37-T-03	TEMP	-100.0	400.0	C	N
3B19	mA	0.0	10.0	V	N
5B30-05	mV	-50.0	50.0	mV	N
5B32-02	mA	0.0	20.0	mA	N
5B34-01	RTD	-100.0	100.0	C	N
5B37-T-03	TEMP	-100.0	400.0	C	N
uMAC-6000	ALL TYPES	0.0	0.0	mV,mA,V,C	Y
NETPAC	ALL TYPES	0.0	0.0	mV,mA,V,C	Y
NETPAC	ALL TYPES	0.0	0.0	mV,mA,V,C	Y
NETPAC	ALL TYPES	0.0	0.0	mV,mA,V,C	Y
NETPAC	ALL TYPES	0.0	0.0	mV,mA,V,C	Y
NETPAC	ALL TYPES	0.0	0.0	mV,mA,V,C	Y
PCLD-7700	RTD	0.0	0.0	C	N
PCLD-7700	mA	1.0	10.0	mA	N
API 4380G	mA	0.0	20.0	mA	N
API 4130G	TEMP	-100.0	100.0	C	N
AF!4001-1G	RTD	-100.0	100.0	C	N
SC-5B31-02	V	-5.0	5.0	V	N
SC-5B31-03	V	-10.0	10.0	V	N
SC-5B41-03	mV	-100.0	100.0	mV	N
SC-5B34-01	RTD	-100.0	100.0	C	N
SC-5B32-01	mA	4.0	20.0	mA	N
SC-5B39-03	mA	0.0	5.0	V	N
SC-5B37J01	TEMP	-100.0	760.0	C	N
SC-5B37T03	TEMP	-100.0	400.0	C	N

Board Data

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Board Name	Sample Rate	Gains	Board Low	Board High	B Unit
AT-MIO-16F-5	200000/S	.5,1,2,5,10	-5.0	5.0	V
AT-MIO-16H-9	100000/S	1,2,4,8	-10.0	10.0	V
AT-MIO-16H-15	71000/S	1,2,4,8	-10.0	10.0	V
MC-MIO-16H-9	100000/S	1,2,4,8	-10.0	10.0	V
MC-MIO-16H-15	71000/S	1,2,4,8	-10.0	10.0	V
MC-MIO-16H-25	45000/S	1,2,4,8	-10.0	10.0	V
DAS-8	4000/S	NO GAIN	-5.0	5.0	V
uCDAS-8PGA	4000/S	VARIETY	-10.0	10.0	V
DT2808		1	0.0	5.0	V
DT2824-PGH		1,2,4,8	0.0	10.0	V
DT2841-L		1,2,4,8	-5.0	5.0	V
RTI-220.STB-AOT	21000/S		0.0	5.0	V
RTI-800	91000/S	1,10,100,500	0.0	5.0	V
1771-IFE	25mS/16 CH	1,2	0.0/-20.0	10.0/20.0	V/mA
1771-IL	500mS/8 CH	1,2	0.0/-20.0	10.0/20.0	V/mA
1771-IXE	1S/8 CH	1	-99.9	99.9	mV
1771-IR	1S/6 CH	1	0.0	100.0	C
CPU-286			0.0	5.0	V
SBC-386			0.0	5.0	V
SBC-486			0.0	5.0	V
PCLD-789		.5,1,2,10,50	0.0	5.0	V
PCLD-889		.5,1,2,10,50	0.0	5.0	V
PI-32L(PC)H			-12.0	24.0	V
ADC-35			-5.0	5.0	V

NOTE: The data on the next page is a continuation of the data on boards.

Board Data (Cont)

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Board Name	Attribute	Board Computer	PLC Interface
AT-MIO-16F-5	ANALOG	AT	N
AT-MIO-16H-9	ANALOG	AT	N
AT-MIO-16H-15	ANALOG	AT	N
MC-MIO-16H-9	ANALOG	PS/2	N
MC-MIO-16H-15	ANALOG	PS/2	N
MC-MIO-16H-25	ANALOG	PS/2	N
DAS-8	ANALOG	AT	N
uCDAS-8PGA	ANALOG		N
DT2808	ANALOG	AT	N
DT2824-PGH	ANALOG	AT	N
DT2841-L	ANALOG	AT	N
RTI-220,STB-AOT	ANALOG	PS/2	N
RTI-800	ANALOG	AT	N
1771-IFE	ANALOG	PLC	Y
1771-IL	ANALOG	PLC	Y
1771-IXE	TEMP	PLC	Y
1771-IR	RTD	PLC	Y
CPU-286	ANALOG	AT	Y
SBC-386	ANALOG	AT	Y
SBC-486	ANALOG	AT	Y
PCLD-789	ANALOG	AT	Y
PCLD-889	ANALOG	AT	Y
PI-32L(PC)H	ANALOG	AT	
ADC-35	ANALOG	AT	

Datalogger Data

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Datalogger Name	Digital Out	PLC Inter	Data Comp	Data Out
MPM-4000	RS-232C	N	AT	RS-232C
DIGI-4	RS-232C	Y	AT,PLC	RS-232C

COMBAT RATION ADVANCED MANUFACTURING TECHNOLOGY DEMONSTRATION (CRAMTD)

**Desirable Characteristics and Requirements for
Production Planning and Control of CRAMTD Facility**
Technical Working Paper (TWP) 51

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March 1992

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1.0 GENERAL

Purpose of the Technical Report

Section 3.4.1 of STP #5 Technical Proposal of contract DLA 900-88-0383 between Rutgers University and the Defense Logistics Agency requires the contractor to identify desirable characteristics and requirements for production planning and inventory control software. The purpose of this technical report is to describe the up to date findings in this area. This is a working document and is subject to revision.

1.1 Background

In the context of Computer Integrated Manufacturing (CIM), the control hierarchy is composed of four levels:

- Level 1 - control of individual unit operations,
- Level 2 - control of the interaction between related unit operations, referred to as the production line or production process,
- Level 3 - control and integration of function on the factory floor,
- Level 4 - Control and integration of functions at the plant level.

Depending on the application, each control level will have a number of functions associated with it. For instance, order processing, purchasing, planning and scheduling, and contract management are some of the functions associated with Level 4. In Level 3, some typical functions are inventory control, quality management and control, and lot tracking. In Level 2, batch control, material handling, and statistical process control are some of the functions to consider. Finally, in Level 1, real time process control and monitoring is an important function to consider.

The above functions can also be classified in a way that different functions within a class are associated with a specific set of tasks. In this respect, we define four classes of

manufacturing related functions: Class of Business Functions, Class of Manufacturing Planning Functions, Class of Product Development Functions, and Class of Manufacturing Control Functions. The Class of Business Functions include such functions as accounting, sale forecasting, product costing, pricing and sales, order processing, and purchasing. The Class of Manufacturing Planning Functions include but not limited to Aggregate Production Planning, Materials Requirements Planning, and Process Planning. The Class of Product Development Functions refer to all the tasks associated with the development of formulas for the new products or the maintenance of the existing formulas. The Class of Manufacturing Control Functions include but not limited to materials management and control, quality management and control, factory floor scheduling, shop-floor control, and maintenance. We note that this classification better suits the scope of the existing software products in the area of production planning and control.

2.0 Functional Model of the CRAMTD Facility

Prior to the specification of software requirements for the planning and control of any manufacturing system, it is required to have a good understanding of the functional architecture of that system. Such an architecture would basically describe the various functions in the system, their input and output, and the relationship between these functions. The architecture of a system can be specified using various existing methodologies such as IDEF0 or Data Flow diagrams. As part of STP#4 a functional architecture was developed using IDEF0 methodology. This architecture basically describes the various functions and their relationships.

Given the functional architecture of the system, the next step is to identify the functions which need to be automated. The main criteria for selecting these functions are the economical and/or technical feasibility. Here, we just concentrate on the Classes of Manufacturing Planning and Control Functions. In the next section, we demonstrate the

software requirements specification for each of the functions in these two classes that need to be automated at least on a partial basis. The specification includes the functional requirements as well as the input and output requirements. The functional requirements define the various functions to be performed by the software. The input requirements define the inputs that are needed by the software to perform its functions. The output requirements define the outputs needed to be generated by the software.

3.0 Software Requirements Specification

In this section, we shall describe the requirements specification for the functions included in the Classes of Manufacturing Planning and Manufacturing Control Functions. The requirements for each software function would include one or more of the following:

- A table describing the relationship between the software function and the functions in the IDEF0 model.
- A general description of the software functions.
- The functional requirements.
- The input requirements.
- The output requirements.

3.1 Aggregate Production Planning

No.	Function Description	Corresponding IDEF0 Functions
1	Contract Aggregate Production Planning	A21411,A21412,A21413
2	Master Production Planning	A2211,A2214,A2212,A22134
3	Personnel Requirements Planning	A2143
4	Lead Time Planning	A112
5	Label Scheduling	

With respect to military contracts there are two levels of production planning. First an

aggregate production plan is prepared over the contract period. The contract planning is done based on a planning horizon that equals the contract period, and the intermediate demand schedule which must be calculated from the contract shipment quantities by offsetting the final shipment scheduled by the anticipated reject rate and the required incubation period. The plan specifies for each product the quantity to be produced and the time of production so that the contract shipment is met. The second planning level is common to both military and civilian products. At this level we prepare a master production schedule. The planning is done over a flexible time horizon, for example, one month. This is a medium aggregate production schedule which specifies the products to be produced over the next planning horizon (e.g., a month). The master production schedule is a rolling schedule which may be revised based on the availability of raw materials and the arrival of new orders.

During each planning horizon, usually several open orders are competing for the same resources (equipment and labor). As part of the aggregate production plan it is necessary to provide the schedule for resource allocation to different open orders. There are basic approaches for capacity planning: finite and infinite. In finite capacity planning, raw materials, equipment, and labor are committed to open orders in accordance to their priorities. In infinite capacity planning, first the manufacturing schedule is prepared irrespective of the available production capacity. Then a plan is generated specifying the required production capacity. If the specified production capacity exceeds the available production capacity, then the manufacturing plan is revised and/or the production capacity is increased.

To compute the personnel requirements, infinite capacity planning is a common approach. As for the machine (retorts, filling machines, etc.) requirements planning, the problem is more complex. The common approach in shelf stable food manufacturing industry is to assign a filling line to only one product during a production shift. This

imposes a very tight restriction on the production capacity. There could be exceptions when two products are quite similar, for example, one product is having one less filling operation compared to another, but the ingredients are identical in all other respects. In such circumstances, the available time of a filling line could be divided between the two products. Such common features among the open orders lessens the constraint on the production capacity to some degree, and calls for some type of "optimal" resource allocation. It is also possible to extend the capacity of some resources should the need arise. For example, some filling lines or retorts may be scheduled to run for additional (overtime) shifts within a given day. But since the time period between filling a tray and putting it in the retort should not exceed a time limit, one cannot extend the available hours for the filling lines indefinitely.

Functional Requirements

- Compute the intermediate demand schedule for contracts - The final demand must be offset by the incubation period and allowance must be made for rejections and rework.
- Sequence the open orders - The function involves prioritizing open orders based on the prioritization rules adopted by the firm. This reflects the application dependent nature of this function which suggests an open structure for the software in this respect. A desirable paradigm for the open structure shall be to provide the user with the ability: (I) to override the system generated priorities, (II) to modify the built-in module in charge of this function.
- Prepare product net requirements - This function determines how much of the required demand for an open order can be satisfied from the finished goods inventory. Finished goods with the same label and product code as the open order are committed. In addition, unlabeled finished goods with the same product code as the open order can also be committed. The net production requirement of a product is the

balance that could not be satisfied by the finished goods inventory.

- Prepare the list of products to be scheduled - This function in conjunction with the material requirements planning prepares the list of open orders which could be produced solely based on the availability of ingredients. This is an ordered list with the ordering done according to the list of prioritized products.
- Generate master production schedule - Three levels of requirements shall be defined for this function. A minimum requirement of this function is to select open orders from the list of products to be scheduled, and allocate time and resources (machine and/or labor) to these orders. There could be a man machine interface for a number of reasons including the case when the operator overrides the automatic selection process. At this level the selection algorithm is straight forward and permits human intervention so as to obtain a better schedule. A more desirable form of this function would possess an algorithm to compute an "optimal" plan according to some cost function subject to some constraints, such as finite machine capacity and finite planning horizon. Still a more desirable requirement for this software function will be an open structure so as the user can modify the built-in algorithm, or define his/her own algorithm.
- Generate contract production plan - This function shall generate quantities of production per time period over the life of the contract, reflecting shipment dates, projected reject and rework, and production capacity.
- Prepare a personnel plan - This function computes the labor requirements to run the production facility using the process plans and the contract production plan for the planning horizon.
- Provide a basis for quoting delivery dates for new orders based on capacity - This function shall provide a promised delivery date for each potential order being quoted by reviewing the orders already in-house, their promised delivery dates, and the

remaining capacity available to be used in the production of the product that is subject of the quotation.

- Production requirements calculation - Given the processing times, process plan, and the production quantity, the production requirements shall be computed.
- Prepare a schedule for labeling finished civilian products.

Input Requirements:

- Final shipment schedule of contracts.
- Incubation holding period.
- Allowance for rejections and reworks (for each product) due to external quality testing.
- Available production capacity during the planning period.
- List of open orders to be processed during the planning period.
- Processing times, process plan and due dates for each open order.

Output Requirements:

- For the contract planning:
 - The time periods (within the contract period) assigned to the production of the combat rations.
 - Quantity to be produced for each product type within each time period.
 - The production resources assigned to each contract.
- For the master production planning:
 - An assignment of orders to be produced by day for an intermediate period; e.g., a month.

- A list of committed finished goods inventory to be shipped against open orders.
- For personnel requirements planning:
 - An estimate of personnel requirements over the life of a contract necessary to achieve the contract aggregate production plan.
 - Labeling schedule for civilian products.

3.2 Materials Requirements Planning

No.	Function Description	Corresponding IDEF0 Functions
1	Explode Material Requirements	A21421,A22131
2	Determine Net Ingredient Requirements	A22132
3	Schedule Inventory Replenishment	A22133
4	Document Material Plan	A21425

Material Requirements planning takes place at two different levels. While performing contract aggregate production planning, a materials plan shall be generated which documents the schedule for consuming each ingredient and material and the vendors who will supply the ingredients and material. To prepare this document it is necessary to perform an ingredient explosion based on the aggregate contract manufacturing plan and military specs which describe the ingredients for each combat ration product and the yield. The selection of vendors is an activity to be performed by the contract administrator in conjunction with the purchasing department. Also, with this document blanket orders are issued for requisition of critical ingredients. Shipment against those blanket requisitions will be activated at the time of master production planning.

At the time of master production planning, material requirements planning is performed for each open order which has positive net requirements. The ingredient explosion would be done based on the formula for each product, ingredient yield, and the net production requirements. At this time, the contract orders to be scheduled for the next planning horizon will have their blanket orders activated. The net ingredient requirements are

calculated by comparing the above obtained gross ingredient requirements to the on-hand inventory level. If the on-hand plus on order is insufficient to meet the production of an open order, a material replenishment request is made and forwarded to Material Management function, otherwise, that open order is added to the list of products to be scheduled.

Functional Requirements

- Explode materials requirements - The function involves the explosion of ingredient requirements for each open order based on its net production requirements and formula (MIL specs for combat rations).
- Compute the net ingredient requirements - The function compares the gross ingredient requirement to the available inventory of ingredients and to the amount on order.
- Schedule for material replenishment - The function specifies the required quantities by time periods. The requests shall be passed on to Material Management function.
- Prepare materials plan - This is for contracts only. The function shall prepare a schedule for releasing key ingredients and the vendor who will supply the ingredients.

Input Requirements:

- Mil Specs for combat rations.
- Formula for civilian products.
- Ingredient yield.
- Product reject rates.
- Manufacturing plan.
- Vendor lot inventory of ingredients and raw materials.

Output Requirements

- Material replenishment requests.
- A list of open orders and corresponding committed material.
- A materials plan for contracts.

3.3 Factory Floor Scheduling

No.	Function Description	Related IDEF0 Functions
1	Production scheduling	A2221
2	Material move scheduling	A2224
3	Retort Scheduling	A2223

A day production schedule indicates which products are to be produced on which equipment for that day. The monthly production schedule, product formula, and the projected production capacity (both labor and equipment) provide the basis for obtaining the day production schedule. Unlike the monthly production schedule which is on a rolling basis, this one is a firm schedule. There are two important constraints, available production capacity and minimum production requirements, imposed on the scheduling process. At the same time, it is important to utilize the production capacity to its highest level.

Retort capacity is one of the common resources shared by different products. Using the day production schedule and the formula (which includes retorting information) a proper schedule must be prepared for the retorts. The retort capacity, retort times, and the maximum amount of time permitted between sealing and retorting operations are among constraints for retort scheduling. At the same time, it is important not to underutilize these expensive equipment.

Given the production schedule for the next day and the formula for the scheduled products, the next step is to develop a schedule to move material from the storage to the shop-floor.

Functional Requirements

- Prepare the day production schedule - This is a schedule of which filling lines and kettles will be assigned to particular products on a given day. At a minimum this function shall consider available labor and equipment in relation to desirable production quantities. If capacity is exceeded, a desirable feature would provide an optimal selection of a subset of orders to be built.
- Prepare the batch sheets - This describes the batching and mixing preparation prior to filling. At a minimum it should include the ingredients to be added by unit of measure and the cooking instruments, if any. A more desirable feature would include textual detail to guide the kettle operator.
- Prepare the retort schedule - This is the day schedule for the utilization of the retort. It should take into account such factors as the time limitations for keeping sealed packages prior to the retort operation. A desirable feature would be optimal allocation of retorts to different products in any given day.
- Prepare the material move schedule - This is a schedule of the ingredients and materials to be moved to the shop floor for production over the schedule day. At the minimum it describes the vendor lots to be moved, their storage location and the shop floor location to be moved. A more desirable feature would be to include the time of day of each move.

Input Requirements

- Monthly production schedule.
- Minimum production quantities.
- Available production capacity.

- Formula for each scheduled product.

Output Requirements

- Daily production schedule.
- Material move schedule.
- Retort schedule.
- Batch sheet.

3.4 Materials Management and Control

No.	Function Description	Corresponding IDEF0 Functions
1	Request Inventory Replenishment	A311
2	Management of Raw Materials	A3131,A3132,A3134,A3136
		A3211,A3212,A3213,A3231
		A3241
3	Management of Finished Goods	A341,A421,A422,A435,A431,A433
4	Lot Tracking	A34

Function 2 above relate to the management of materials from the time the replenishment requests are generated to the time that the materials are released to the shop floor. They also relate to the management of unused materials returned from the shop floor and the finished goods inventory. The management of work-in-process inventory is considered to be part of the Shop-Floor function.

Function 6 above refers to lot tracking and traceability. This will be capable of being implemented down to the vendor lot number level. Complete traceability of packages will include filling line and retort cook identification, as well as "where shipped to" record. A received material shall be tracked by vendor lot, quantity, location, status records, and production lot in which it is used.

At the least, the Materials Management and Control function shall provide the operator with the necessary information to move material from one location to another as

requested by another function (e.g., move ingredients from the storage to the shop-floor according to the material move schedule). This function should provide integrity checks of actual material movements against planned material movements.

Functional Requirements

- **Receive incoming materials** - This function records the acceptance of raw materials. At a minimum it allows terminal entry of information at a remote location. A more desirable function will allow automatic identification at point of material acceptance. This function should match shipping documents to open purchase orders. The Quality Assurance and Purchasing functions should be automatically notified of materials received.
- **Return reject material** - This function involves the initiation of the return of material based on quality assurance test failure.
- **Store material** - This function must retain material storage records by vendor lot number, quantity, location and status for raw material and by pallet number, location, and status for finished goods.
- **Release and restore material** - This function records the release of materials to the shop floor and the return of unused materials from the shop floor. At a minimum it allows terminal entry of information at a remote location. A more desirable function shall include automatic identification. This function will include integrity checks previously defined.
- **Ship finished goods** - This function records the shipment of finished goods against open orders. At a minimum it allows terminal entry of information at a remote location. A more desirable function will allow automatic identification at a point of shipment. This function shall update open orders and provide information to the Accounting function for invoicing purposes. It shall also provide integrity checks against the shipping

schedule.

Input Requirements

- Bill of lading.
- Material Move Schedule.
- Incoming Material Acceptance data.
- Completed Subassembly data.
- Variance/Rework/Disposition data.
- Incubation data.
- Container Evaluation data.
- Pallet Record.
- Labeling Schedule.

Output Requirements

- Receiving data.
- Return data.
- Shipping data.
- Disposition data.

3.5 Shop-Floor Control Function

No.	Function Description	Related IDEF0 Functions
1	Process Control and Monitoring	See Below
2	Supervisory Control and Monitoring	See Below

In the CRAMTD facility there are presently six major processes associated with the shop

floor: Preparing Ingredients (IDEF0 Node A321), Mixing and Cooking Ingredients (IDEF0 Node A322), Filling Packages (IDEF0 Node A352), Sealing Packages (IDEF0 Node A324), Retorting Packages (IDEF0 Node A325), and Casing Packages (IDEF0 Node A33). Each of these processes consists of several concurrent or sequential sub-processes (or activities). For example, the process of Filling Packages consists of two sub-processes: Filling MRE Pouches and Filling Tray-Packs. These two sub-processes are concurrent in that they go on simultaneously. At the same time, these two sub-processes could reach into a conflict state with each other when both are competing for the same resource, e.g., kettles, material transporters, operators, so on. The IDEF0 Functional Model prepared under STP#4 illustrates the activities associated with each of the above processes. There are two levels of control and monitoring associated with the shop floor processes: local process control/monitoring and supervisory process control/monitoring.

Typically an individual process (e.g., Filling Packages) involves some variables (e.g., motor speed of conveyor belt in the filling line) which must be controlled. These variables are usually continuous. The control/monitoring of these variables is one of the activities to be performed by the local Process Control/Monitoring associated with that process. This task (sometimes referred to as real time control) includes three subtasks or sub-functions: Measuring, Monitoring, and Adjusting process variables or parameters. Measuring the process variables is achieved by using sensors or transducers. Monitoring of the process parameters is achieved by analyzing the sensory data. Adjusting the process variables is an action performed following the data analysis. In other words, an adjustment of the process variables deemed necessary at the time that values of these variables are found to be deviating from their target values. The adjustment of the process variables may also take place as a consequence of deviation in the product characteristics. This happens following the online or offline testing analysis of the product quality characteristics. This is what we will call the Statistical Process Control

task or subfunction. One last task associated with the Process Control/Monitoring refers to the coordination or sequencing of intra-process activities associated with each individual process. This is what we call sequential control of the process. While performing sequential control, the process is considered to be discrete, representing the conditions of the inter-process activities. According to the sequential control logic, the input values (or signals from sensors) are applied to the current process conditions and appropriate output signals are generated. Subsequently, these output signals change the process state.

It is desirable to completely automate all the tasks associated with the Process Control/Monitoring function. The software in charge of this function shall acquire real time data as it is generated by the sensors, analyze the data, and select appropriate control actions (this is true for all three control tasks). TWP#46 discusses two general approaches for the implementation of these tasks. One approach calls for the use of PLCs for data acquisition and performing such control routines as PID control, control of continuous process variables, and sequential control. Here the statistical process control task is performed on one or more general purpose computers (e.g., PCs) networked with the PLCs. The PLCs forward the necessary data that they have acquired to these PCs. The other approach uses general purpose computers (e.g., PCs) to perform data acquisition and all the control and monitoring tasks.

A list of attributes or characteristics which must be considered while selecting the process control and monitoring software is given in TWP#46. There are three basic class of attributes to consider: class of attributes which relate to computer hardware and external software requirements, class of performance characteristics, and class of attributes relating to process control capabilities. The performance characteristics relate to the data acquisition and interfacing requirements.

Unlike the Process Control/Monitoring which deals with the intra-process activities of

the individual processes, the Supervisory Control/Monitoring shall be in charge of coordinating and monitoring the inter-process activities associated with the processes in the CRAMTD shop floor. The coordination or sequencing is performed according to a sequential control logic and in conjunction with the short term production schedules (e.g., day production schedule). The control logic shall be structured in a hierarchical manner so that the inter-process information and command flow takes place only through the supervisory controller. The supervisory control shall also be in charge of managing the material flow within the shop floor. It is desirable that this function is automated as much as possible.

Functional Requirements

- Process control and monitoring for individual processes - This involves real time process control and monitoring as well as sequential control for each individual process. The statistical process control is described under the Quality Management and Control function.
- Supervisory control and monitoring - This function involves the sequential control of all the individual processes together. This also involves the control of materials handling system.
- Information processing and storage - This function involves the compression and summarization of the sensory data collected from the individual processes. The information shall be forwarded to and stored in a data base to be used by higher level control functions.
- Work-In-Process material management and control - This function shall control and monitor the materials movement in the shop floor.

Input Requirements

- Desirable parameter settings for each process variable.
- Data describing the actual state of the process in real time for controlled variables.
- Day production schedule.
- Status data from individual processes.
- Instructions for logging historical data from processes.

Output Requirements

- Preprogrammed process control actions.
- Historical data for data logging and analysis.
- Summary statistics for permanent archiving.
- Parameter settings downloaded to PLCs.
- Corrective actions for out of control inter-process conditions.

3.6 Quality Management and Control

Quality management and control deals with the activities required to ensure the quality of the product from receiving and actual production to shipping.

This is usually done by performing two types of quality control activities: Off-line and On-line. The off-line quality control involves design of engineering experiments to determine the best settings of processes in the production line which ensure robustness of the processes to variations in material, environment, ... etc. In other words, the settings are selected such that the variability of products is minimized.

On-line quality control is a set of activities which are performed during production for the purpose of product and statistical process control. They involve sampling of products and measuring their characteristics, monitoring and controlling the settings of the

processes and adjustments of the settings when deviations from predetermined values occur.

For this phase of the CRAMTD project we will focus mainly on on-line quality control activities: measurements, monitoring, and adjustments. In other words, the characteristics of the product as well as the parameters of the processes are frequently measured and monitored and the processes are adjusted when needed. We note that these tasks require a combination of sensors, data acquisition hardware, process control and quality control hardware and software. Here, we shall concentrate only on the software requirements.

Functional Requirements

- **Parameter setting** - This function provides the user with an environment to define or set the necessary parameters (e.g., sampling rate, analog or digital, range) for data acquisition from each input channel. The user shall be given a wide selection range for each parameter.
- **On line quality and statistical process Control** - This function shall provide statistical analysis of sensory data collected from product characteristics. Both variable and attribute quality characteristics shall be considered. The function shall include basic and advanced features of SPC. The user shall also be provided with an appropriate interface and programming environment to develop user defined analytical procedures. Following the analysis the function shall generate appropriate output signals to adjust the controlled process.
- **Off line quality control information processing** - The function shall be capable of accepting information from off-line experimental laboratory experimentations
- **Timing features** - The function shall provide extensive timing features: use counter/timer to count pulses, measure frequency, generate pulses, or time intervals.

- Information display - The function shall be capable of displaying both raw and processed (analyzed) data collected from the sensory devices or from off line sources. The type of display (graphical or non-graphical) shall be selected by the user.
- Information processing and storage - This function involves the compression and summarization of the sensory data and the storage of the processed data in a format to be used by the other CIM functions.
- Distributed control - The function shall be capable of exchanging information with other quality control and management functions residing in different hardware platforms.

Input Requirements

- The system should be capable of accepting different forms of input (e.g., analog, digital, pulse or smoothed pulse input, delta time, derivative, pulse rate, smoothed pulse rate, key board). It must also accept standard file types (for instance, use of space, comma, tab-delimited ASCII or binary formats).
- Minimum number of input channels is 16
- The system shall provide drivers for AB PLC and a wide range of input/output boards.

Output Requirements

- Provide the standard \bar{R} , \bar{X} , p , and c quality control charts.
- Provide feedback in digital or analog (voltage or current) forms.
- Provide statistics about the processes being monitored in forms such as: Standard file format and Graphics displays.
- Provide desirable parameter settings for processes.

3.7 Maintenance Management

No.	Function Description
1	Equipment Management
2	Maintenance Planning and Control
3	Personnel management
4	Inventory Management
5	Purchasing Management

The maintenance department is expected to undertake, among others, the following functions: maintenance of production and plant equipment, maintenance of building and grounds, preventive maintenance, alteration to existing equipment, new installation of equipment, control of spare part's inventory, and purchasing of spare parts. In some cases, it may be necessary to use outside contractors for some of maintenance activities.

Maintenance tasks can be classified into: work order task (WOT), or preventive maintenance task (PMT). An WOT for a given equipment may extend over one day and has to be requested and approved by appropriate personnel. An PMT for a given equipment, on the other hand, is performed according to a specified frequency and is assigned a given priority. Associated with a given maintenance task (WOT/PMT) are estimates of the parts and labor required.

Each maintenance personnel has a given specialty. In order to further their skills, the maintenance personnel are expected to attend various training programs. These training programs may be in-house or outside ones.

Functional Requirements

- Prepare preventive maintenance schedule - Every day, the maintenance module generates a list of those equipment that are due for a given preventive maintenance tasks together with the estimated parts and labor requirements. The status of those

equipment scheduled for an POT should set accordingly thus, indicating its unavailability during that time period.

- Prepare history of work order and preventive maintenance tasks - This function generates history of WOTs and PMTs performed on a given machine. For each WOT/PMT the actual staff hours and parts are computed and contrasted with their respective estimates.
- Spare parts receipt and withdrawal - This function records the accepted parts. At a minimum it allows terminal entry of information at a remote location. A more desirable function will allow automatic identification at point of material acceptance. This function should match shipping documents to open purchase orders. Year-to-date issues/returns, minimum-required-quantity, and reorder-quantity for each part should be maintained.
- Charging/crediting maintenance tasks - This function will charge/credit appropriate WOT/PMT of any parts withdrawal.
- Spare parts reordering - This function reports on all parts that are due for reordering at a given day as well as the associated reorder quantity.
- Maintenance staff - This function keeps track of and reports on information related to overtime, training, and vacation of each staff member.

Input Requirements

- For each equipment, the list of preventive maintenance tasks together with the corresponding frequency, and an estimate of the labor and parts requirements.
- Maintenance work orders
- Spare parts for each of the equipment

- List of vendors and the parts each can supply
- Maintenance department's employees information
- Training programs related information

Output Requirements

- Preventive maintenance schedule for each equipment
- Report on the status of all on-going WOT/PMT.
- History per equipment of WO/PM tasks issued during a given time period
- Cost (labor and parts) summary per equipment over a given time period
- Report on overtime, training, and vacation for each employee at the maintenance department

COMBAT RATION ADVANCED MANUFACTURING TECHNOLOGY DEMONSTRATION (CRAMTD)

Process Control Software Review
Technical Working Paper (TWP) 54

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Rutgers, The State University of New Jersey
June 1992

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"Process Control Software Review"

Technical Working Paper (TWP) 54

Mohsen A. Jafari and James McPhail

Abstract

This report describes the surveyed software packages for data logging/monitoring/process control. For each package, the hardware platforms, functionality, software and hardware interfacing, and performance characteristics are described. The information has been obtained from the literature provided by the software vendors or distributors. A standard survey format is used in reporting software characteristics.

1. General

Purpose of the Technical Report

Section 3.4.2 of STP#5 Technical Proposal of contract DLA 900-88-0383 between Rutgers University and the Defense Logistics Agency requires the contractor to perform a comprehensive survey of industry for the existing software on data logging/monitoring/process control. The purpose of this technical report is to describe some of these software packages. This is a working document and is subject to revision.

2. Description of the Existing Software

Here, we describe some of the existing software package on data logging/monitoring/process control. For each package, we describe the hardware platforms, functionality, networking, software interfacing, hardware interfacing, and performance characteristics. The information has been obtained from the literature provided by the software vendors or distributors during the course of our survey which started early summer of 1991 and ended late spring of 1992. Unfortunately, the catalogs provided by the vendors sometimes do not give a precise description of what is actually in the software. Also, sometimes the catalogs do not provide a precise definition of the terms used in them. In summary, we found it quite difficult to have a comprehensive understanding of the different features of the software based on the information provided in the catalogs.

We should emphasize that the purpose of this report is not to compare different packages. It only describes some important features of each software package. We believe that this report only provides some basic information for selecting the most suitable software package for the CRAMTD application.

The Data Master by Dalon Controlled Productivity Inc.

The foundation of The Data Master is a background program that scans PLCs or dedicated I/O on a continuous basis, creates logs, and loads them into Lotus 1-2-3 worksheets.

Basic Platforms

IBM PC/XT, AT, or fully 286 compatible

Functionality

SPC is available including XBAR and R charting.

Expandability - Not Mentioned.

Ladder Logic Control - Communication with PLCs exists, but ladder logic control not mentioned.

Networking/ Data Input

NETBIOS, RS232, RS422, Ethernet

Software Interfacing

Reports are generated with Lotus 1-2-3 or as text files

Hardware Interfacing

PLCS:	Allen Bradley	Mitsubishi	Square D
	Omron	GE Fanuc	Telemecanique
	AEG Modicon	Seimens	GEC

Distributed I/O or Single I/O Boards:	
Burr Brown	Sixnet
Opto 22	Analog Devices

Performance Characteristics

Scan Rate: Minimum Update Time = 50 mSec
Maximum Update Time = 3600 Sec

Alarm Types: 1 Sec Standard Trend Analysis

Min Scan: 1 sec/point

Max Scan: 1 hour/point

Max. Number of Input Devices/Communication Ports: Not Mentioned

Reference: Catalogs provided by BASIC Technologies, dated Nov. 1991.

Factory Link by USDATA

Basic Platform

IBM PC/AT, PS/2, 7531, 7532, 7541, 7542, 7552, 7561, 7562 and 100% compatibles (286 & 386) with:

MS-DOS using MS Windows

OS/2

OS/2 with IBM Distributed Automation Edition

VMS

UNIX

- HP-UX

- AIX

- ULTRIX

- SCO/UNIX

Functionality

SPC: Provides on-line SPC monitoring, control and alarms, with automatic corrective action capability

- X-bar and Range

- Split Means

- X-bar and Sigma

- Histograms

- Moving Average, Moving Range

- Process capability indices

- Exponentially Weighted, Moving Average

On-line analysis of data from plant floor equipment, manual entry, or calculated values. dBase III compatible file formats permit other statistical programs to access and analyze data.

Ladder Logic Control: Not Mentioned

Networking/Data Input

IBM NetBIOS, Ethernet, IBM PC-Network, Novell Network, IBM Token-Ring, TCP/IP, Digital DECnet

Software Interfacing

- On-Line Relational Database is available:

Information is transferred between the real-time database and multiple records in the Relational Database, with transfers initiated or scheduled by any system event:

- Functions:

SQL/SPC Database

Operator log book; Audit trail

Batch recipe upload/ download

Data capture; Report generation

Machine Setup; Diagnostics

Data interchange

Operator messages

dBase compatible; does not require Ashton-Tate dBase software to be loaded.

- Provides software libraries, tools and documentation required by C programmers to develop unique programs.

MAP/MMS Support

- Peer-to peer, real-time transfers between real-time database and MAP devices.
- Supports MMS File Management Services.
- Other MAP applications can access Factory Link as if were a device.

Hardware Interfacing

Provides interfaces to PLCs, RTUs, RTPs, Loop Controllers, Distributed I/O, Data Collection Terminals, Bar Code Scanners and other equipment:

Allen Bradley Data Highway I, II, II+, KT
 Analog Devices, uMAC
 Burr Brown TM2700 Data Entry Terminal
 Eagle Signal Eptak
 Eurotherm 808 Controller
 Fisher-porter Micro DCI
 GE-Fanuc Series IJR, 3, 5, 6, 6-Plus and PCIM (GENIUS BUS)
 GECGEM80 except MicroGEM
 Honeywell TDC 3000 PCSI, UDC
 Leeds & Northrop Micromax, Speedomax
 Modicom MODBUS I, II, and Plus
 Opto/22 Optomux
 SAIA PCA2 and PCD6
 Siemens "U" Series w/CP524 or CP525
 Square D Sy/MAX & Sy/LINK
 Texas Instruments TIWAY and point-to-point for TI565, TI520, TI530, PM550, 5TI
 Telemecanique Uni-Telway & Drives
 Transition Technology "Transport"
 Westinghouse

Performance Characteristics

Scan rate - Not Mentioned
 Alarm Types - Not Mentioned
 Max. Number of Input Devices/Communication Ports - Not Mentioned

Reference: Catalogs provided by US DATA, dated Nov. 1991.

Labtech Control by Laboratory Technologies

Basic Platform

IBM PC-XT, AT, PS/2 386 & 486
MS-DOS with Expanded Memory Support and MS-Windows
OS/2
UNIX Workstations with X-Windows
DEC VAX
Apple Mac II, IIfx

Functionality

SPC - On-Line SPC charts are supported through built-in statistical functions, including mean, standard deviations, and moving averages. X-BAR and R charting can be generated from this.
Expandability - Not Mentioned

Ladder Logic Control - Not Mentioned

Networking/Data Input

Peer-to-peer or file server based over a variety of protocols including Novell, 3Com, MAP RS-232/422, GPIB.

Software Interfacing

Relational Database - Data can be logged into a SQL database or dBase III for further analysis or archiving.

Higher Level Software - BASIC, C or Pascal can be used to write a custom interface so an untrained operator can perform experiments or control production processes.

Hardware Interfacing

PLCs: See the reference
I/O Boards: See the reference

Performance Characteristics

Scan Rate: Not Mentioned
Alarm Types: Multiple alarm states (hi-hi, high, normal, low, and lo-lo)
Max. Number of Input Devices/Communication Ports: 16

Reference: Catalogs provided by Laboratory Technologies, dated 4/91.

Graceful Automation by Digitronics *SIXNET*

Basic Platforms

IBM PC/XT, AT, PS/2 386
MS-DOS
OS/2
UNIX

Functionality

SPC - Not Mentioned.

Ladder Logic Control - Not Mentioned.

Networking/Data Input

SIXNET, RS-232/422,485, RTU230 and RTU100 packaged systems

Software Interfacing

Relational Database - Not Mentioned

Higher Level Software - "C" programming available.

Hardware Interfacing

Dedicated RTU I/O Package Systems

Performance Characteristics

Scan Rate:	Not Mentioned
Alarm Types:	Not Mentioned
Max. Number of Devices/Communication Ports:	Not Mentioned

Reference: Catalog provided by Digitronics, dated 10/91.

ONSPEC by Heuristics, Inc.

Basic Platforms

IBM PS/2 Models 50, 60, 70, 80 IBM Industrial computers and compatible computers, running OS/2 VMS, AS/400

Functionality

SPC : ONSPEC SQC/SPC is a function-key and menu driven program for statistical quality/process control. The package can handle up to 99 on-line variables with time, batch, or event-based sampling. Real-time data is retrieved through an ONSPEC I/O Template. With the off-line mode included in the package, data is retrieved from historical files or lab data is entered manually.

ONSPEC SQC/SPC provides the following features:

XBAR & R/S Chart	User Configurable Alarm Standards
Individual Chart	Process Capability Analysis
XBAR & S Chart	PC, Cpk, PIST, PIPC
Moving Average Chart	Data Archiving
EWMA Chart	User Comments and Notes
Histogram	Batch Reporting of all Screens
Cusum Chart	ASCII Raw Data Output
2D and 3D Graphics	Interface to Other Packages
On-line & Historical SQC	Automatic Startup & Warm Start
Time, Batch, and Event-based Sampling	Password Option
On-line SQC Alarms	Data Scrolling on Chart
Selectable Alarm Standards	Limits Calculated with Distribution Type

Ladder Logic Control - Available

Networking/Data Input

ONSPEC LSO (Large System OnNet) software connects up to 256 workstations in a standard networking environment. LSO utilizes either named pipes or Netbios features in the OS/2 operating system, and has built-in support for IBM's Distributed Automation Edition (DAE) and POMS. LSO also supports Token Ring and TCP/IP

Software Interfacing

Relational Database - Not Mentioned

Higher Level Software - ONSPEC supports Microsoft C, Fortran, and Pascal to create custom reports or to perform extensive calculations on ONSPEC data.

MRP II interfacing available with AS/400 version.

Hardware Interfacing

The following is a sample of ONSPEC interfaces:

Adac	Kinetic Systems CAMAC
Adatek Power Spec	Measurex Data Freeway
Allen-Bradley PLC-2, PLC-3, and PLC-5	Measurex Simplex
Analog Devices uMAC 4000	Mettler
Analog Devices uMAC 5000	Mitsubishi
Analog Devices uMAC 6000	Mitutoyo MUX-40
Bailey Net 90	Modicon Modbus RTU/ASCII
Bristol Babcock RDX 3350/80	Molytek 2702
Butler National	Moore Product Micro 352
Control Junction ICI	NDC
Daniel Industries 2500	OPTO 22 OPTOMUX/LC2
Daniel Industries Codan	Reliance Automate
Data Scan	Rosemount MCVU
Data Translation 2801A	Siemens Teleperm D
Datam Honeywell Microswitch	Siemens Simatic S5/S25
Elan Energy Systems TTY	Siemens Ethernet Sinac/H1 (High-speed I/O)
Fischer & Porter Chameleon/Supervisor	Square D SYMAX
Fisher Controls Provox Univox	Tano Model 5
Fisher Controls DPR 900	Telemecanique
Fluke Helios 1	Texas Instruments TIWAY
Foxboro 99 UCB/SC	Texas Instruments 530
Foxboro M/760/761	Texas Instruments 550
GE Series 6	Toshiba TOSDIC/243
Harrel	Turnbull 6000
Honeywell Gateway 300/400	UNISOURCE 8000
Honeywell IPC 620	Ultrasonic Array Sonic Gauge
Honeywell LCI/SSC	Wahl/Azonics Data Force
Honeywell PCSI	Westinghouse Numalogic 700, 900, 1100
Honeywell 4500	Westinghouse GPC 1500

Performance Characteristics

Scan Rate:	Not Mentioned
Alarm Types:	Not Mentioned
Max. Number of Devices/Communication Ports:	Not Mentioned

Reference: Catalog provided by Heuristics Inc., dated 1991.

EasyMAP by PROCOS A/S**Basic Platforms**

IBM PC/AT, PS/2 or compatible running OS/2

Functionality

SPC - Internal SPC functions are not mentioned. Microsoft Excel is included as a real-time or on-line spread sheet to allow the user to create statistical process control charts.

Ladder Logic Control

Networking/Data Input

MAP 3.0, MMS, Ethernet, and Token Ring.

Software Interfacing

Relational Database - EasyMAP supports the Oracle relational database, thus facilitating use of Oracle's 4 GL application tools for access to process data.

Hardware Interfacing

PLCs - Allen Bradley, Siemens, and others.

I/O Boards - Not Mentioned

Performance Characteristics

Scan Rate: Not Mentioned

Alarm Types: Not Mentioned

Max. Number of Devices/Communication Ports: Not Mentioned

Reference: Catalog provided by Application Integration Management Corporation, dated Jan. 91.

AIMAX-PLUS (A+) by TA Engineering

Basic Platforms

IBM PC/XT, AT, or PS/2 386 compatibles. Industrial computers

Functionality

On-Line SPC is available

- XBAR & R charting
- XBAR & S charting
- Displays and logs 5 levels of SQC Alarms X, A, B, C & D

Ladder Logic Control - Not Mentioned

Networking/Data Input

A+ LAN function is NETBIOS compatible. It uses the NETBIOS LAN manufacturer's (e.g., Novell, 3 COM, and Lartastic) adapter cards & LAN system software with A+'s and the A+ LAN driver for the LAN function.

Software Interfacing

Relational Database - Not Mentioned

Higher Level Software - Microsoft C or Quick C can be used for programming to access A+ Point Tag database for control, analysis, and reporting. In addition, A+ supports the Lotus @FACTORY function.

Hardware Interfacing

PLC Drivers - Allen-Bradley
GE-Fanuc
Honeywell
Horner Electric
Mitsubishi
Modicon

Omron
Reliance Electric
Seimens
Square D
Texas Instruments-1, 2, 3
Westinghouse

I/O Drivers - Acromag
Analog Devices-1, 2, 3
Computer Products
DGH
Dutec

GE-Fanuc
Grayhill
Moore Industries
Opto 22

Performance Characteristics

Scan Rate:

Not Mentioned

Alarm Types:

30 Groups w/ 18 points per group

Max. Number of Input Devices/Communication Ports: 4

Reference: Catalogs provided by TA Engineering, dated 1991.

PMIS - Process Management Info Systems by Bradley Ward Inc.

Basic Platforms

- HP/9000 Series 300, 400, 800
- HP/1000A
- Supports IBM PC's as operator workstations
- HP-UX operating system with X windows

Functionality

SPC - process data can be passed to other software packages like SAS for analysis.

Ladder Logic Control - Not Mentioned.

Networking/Data Input

Supports Ethernet, TC/IP.

Software Interfacing

Relational Database - PMIS automatically collects real-time data for historical logging into standard SQL databases and statistical packages such as ORACLE, ALLBASE, INGRES, and SYSDATABASE.

Higher Level Software - Includes higher-level procedural language, RACHEL, for custom application development.

Hardware Interfacing

Supported Devices:

Allen-Bradley PLC-2, 3, & 5 On DH-1, 2, & Plus	Seiko RT 3000 Robot
Allen-Bradley Network DTL-UX	Unimation UNIMATE Robot
ALL Modicon PLCs / MODBUS	ICORE Checkweigher
All Texas Instruments PLC / TIWAY	Mettler Scale
General Electric Series 6 PLC	HP3852 Instrument
Westinghouse PLC	HP3497 Instrument
Honeywell IPC/620 PLC	HP48000 Instrument
Foxboro DCS / Foxnet	NETPAC Analog Controller
Fisher DCS / CHIPS (CHIP/1000 & CHIP/9000)	DGH Analog Controller

Performance Characteristics

Scan Rate:	Not Mentioned
Alarm Types:	Not Mentioned
Max. Number of Input Devices/Communication Ports:	Not Mentioned

Reference: Catalogs provided by Bradley Ward, dated 9/91.

Solution DB by APT Engineering

Solutions DB is a relational database that links plant process control (ladder logic included) with IBM compatible PC's.

Basic Platforms

IBM 386, 486 PC or compatible

Functionality

Statistical Process Control - On and off-line SPC is available within Solutions DB.

Ladder Logic Control - Solutions DB provides ladder logic to control the process.

Networking/Data Input

Not Mentioned.

Software Interfacing

Relational Database - No additional databases can be interfaced with the Solutions DB.

Higher Level Software - Not Mentioned.

Hardware Interfacing

PLC Drivers - Solutions DB links their relational database to the plant floor control PLC but a list of drivers was not mentioned.

I/O Boards - Not Mentioned.

Performance Characteristics

Scan Rate:	Not Mentioned
Alarm Types:	Not Mentioned
Max. Number of Input Devices/Communication Ports:	Not Mentioned

Reference: Catalogs provided by APT Engineering, dated Nov. 1991.

Control View by Allen-Bradley**Basic Platform**

IBM PC/AT PS/2 286, 386

Functionality

Statistical Process Control - Not Mentioned

Ladder Logic Control - Not Mentioned

Networking/Data Input

LAN/PC or Ethernet running Novell NetBIOS, Data Highway II, Data Highway + and RS232.

Software Interfacing

Relational Database - Not Mentioned

Higher Level Software - Provides C-Tool kit (Microsoft C) to develop custom programs that work in concert with Control View's Core and options.

Hardware Interfacing

PLC Drivers - Allen-Bradley and Modicon

I/O Boards - Not Mentioned

Performance Characteristics

Scan Rate:	Not Mentioned
Alarm Types:	Not Mentioned
Max. Number of Input Devices/Communication Ports:	Not Mentioned

Reference: Catalog provided by Allen-Bradley.

Rosemount 3 by Rosemount**Basic Platform**

Not Mentioned

Functionality

Statistical Process Control - Not Mentioned

Ladder Logic Control - Not Mentioned

Networking/Data Input

Ethernet, RS-232-C, RS-422-A.

Software Interfacing

Relational Database Interfacing - Not Mentioned

Higher Level Software - Not Mentioned.

Hardware Interfacing

PLC Drivers - Interfacing with PLCs is available.

I/O Drivers - Rosemount 3 provides I/O card cages (Flex Terms) with dedicated field interface cards providing analog, contact, pulse, and temperature I/O.

Performance Characteristics

Scan Rate:	Not Mentioned
Alarm Types:	Not Mentioned
Max. Number of Input Devices/Communication Ports:	Not Mentioned

Reference: Catalogs provided by Rosemount, dated Nov. 1991.

P-CIM by AFCON**Basic Platform**

IBM XT, AT, 286 based or 100% compatible
 PS/2 models 30, 50, 60, 70, 80
 MS-DOS, MS Windows, OS/2

Functionality

Statistical Process Control - P-CIM supports real-time SPC techniques, charts, and reports:

XBar & R	p & np Charts
XBar & S	u & c Charts
Moving Xbar & R	Gauge R & R
I & R	Loss Function
CuSum	Skewness & Kurtosis
Pareto	

Ladder Logic Control - Not Mentioned

Networking/Data Input

Any NetBIOS compatible (Token Ring, Ethernet, Arcnet, Novell, 3-COM), RS-232.

Software Interfacing

Relational Database - Not Mentioned

Higher Level Software - Optional development tool kits are available to allow user written custom programs.

Tool kits include functions for specialized network and PLC communication development.

driver

Hardware Interfacing

Supported Protocols -

Action I/O Pack	Hitachi PCC	Procontic
Allen-Bradley Data Highway	Honeywell 620 Series	Siemens SI1525
Allen-Bradley Data Highway	Instem Link-On 2	Siemens Sinec L1
Allen-Bradley KT Module	Izumi	Siemens Sinec H1
Allen-Bradley PLC	Limatorque DDC 100	Simplex 2120
Allen-Bradley I/O Scanner	Micon Loop Controller	Square D MICRO 1 (Izumi)
Analog Devices MCComm	Mitsubishi Series A	Square D SY / LINK
Andover Controls	Modicon Modbus - RTU and ASCII	Texas Instruments Direct
Dutec I/O Plexer	Modicon Modbus II	Texas Instruments TIWAY
Foxboro 760, 761	Modicon Modbus Plus	Westinghouse 700, 900, 1100, 1200, 1250
GEC Gem80	Modicon X-85	Yokogawa UT30 / UT40
General Electric Series 1,3,5,6,6+	Omron Sysmac	
General Electric Genius	Opto 22	Others.

Performance Characteristics

Scan Rate:	0.5 seconds
Alarm Types:	Unlimited
Max. Number of Input Devices/Communication Ports:	6 Serial Ports

Reference: Catalogs provided by AFCON, dated Oct. 1991.

VIEWpoint by Tele-Denken

Basic Platform

IBM PC/AT, PS/2 or 7531, 7532, 7552 Industrial Computers.

Functionality

Statistical Process Control - SPC is limited to X-Bar & R charting, historical charts, data history charts, and histograms.

Ladder Logic Control - VIEWpoint provides a ladder logic control program.

Software Interfacing

Relational Database - Interfacing not mentioned
Higher Level Software - Not Mentioned

Networking - The network version works on any NetBIOS compatible (IBM, Token Ring, Novell, Arcnet, Ethernet, etc.).

Hardware Interfacing

Supported Protocols:

Allen-Bradley	Siemens
Modicon Modbus	Texas Instruments
GE Fanuc	Cincinnati Milacron
Reliance Electric	Foxboro
Square D	OPTO 22

Performance Characteristics

Scan Rate:	Not Mentioned
Alarm Types:	Not Mentioned
Max. Number of Input Devices/Communication Ports:	Not Mentioned

Reference: Catalogs provided by Tele-Denken.

CIMPROC by Data International**Basic Platform**

IBM PC/AT, PS/2 or Compatible

VAXStation 3100 or MicroVax 2000/3000 running VMS

Functionality

Statistical Process Control - SPC module runs in a standalone mode or as an integral part of CIMPROC.
Provides X-Bar & R charting, control charts, and histograms.

Ladder Logic Control - Not Mentioned

Networking/Data Input

RS-232/ 485/ 488

Software Interfacing

Relational Database - Interfacing not mentioned.

Higher Level Software - Not Mentioned

Hardware Interfacing

Drivers Available: Allen-Bradley, Honeywell, Modicon, Moore, Opto 22, Reliance, Siemens,
Yokogawa.

Performance Characteristics

Scan Rate:	Not Mentioned
Alarm Types:	Not Mentioned
Max. Number of Input Devices/Communication Ports:	Not Mentioned

Reference: Catalogs provided by Data International, dated Sept. 1991.

Advantage 286 by Total Systems Resources**Basic Platform**

IBM 286 / 386 or compatible

Functionality

Statistical Process Control - Only data trending is mentioned.

Ladder Logic Control - Not Mentioned

Networking/Data Input

RS- 232/ 422

Software Interfacing

Relational Database - Interfacing not mentioned

Higher Level Software - Not Mentioned

Hardware Interfacing

PLCs - Allen-Bradley, General Electric, MODBUS, Square D, TIWAY, TI Task Code, UTICOR

I/O Boards - Acromag, Bristol, Hewlett Packard, Lee-Dickens, Omron, OPTO 22, PARVUS, RUGID, TI MICRO ETI.

Performance Characteristics

Scan Rate: Not Mentioned

Alarm Types: Not Mentioned

Max. Number of Input Devices/Communication Ports: Not Mentioned

Reference: Catalogs provided by Total Systems Resources.

Genesis by Iconics

Basic Platform

IBM AT, PS/2 (Models 50, 55, 60, 70, 80)

Functionality

Statistical Process Control - X-Bar, R, and S control measures are calculated.

Ladder Logic Control - Not Mentioned

Networking/Data Input

GEN-NET: Fully NetBIOS and Novell compatible. Runs on either Ethernet, direct ARCNET topologies, Token-Ring, or Novell LAN topologies, RS- 232/ 422.

Software Interfacing

Relational Database - Interfacing not mentioned

Higher Level Software - Microsoft "C" is provided to create and implement custom applications such as interfacing with other computers.

Hardware Interfacing

Genesis supports over 100 drivers.

Performance Characteristics

Scan Rate: .05, 0.1, 0.25, 0.5, 1, 2, 6, 12, 30 Seconds

Alarm Types: Not Mentioned

Max. Number of Input Devices/Communication Ports:6

Reference: Catalogs furnished by Iconics, dated April 1991.

Camile by Dow Chemical Co.**Basic Platform**

IBM 286/ 386 or compatible

Functionality

Statistical Process Control - Not Mentioned
Ladder Logic Control - Not Mentioned

Networking/Data Input

Networking capabilities via Token Ring, Ethernet, or Phone Net, RS- 232.

Software Interfacing

Relational Database - Interfacing Not Mentioned
Higher Level Software - Not Mentioned

Hardware Interfacing

PLCs - Drivers not mentioned
I/O Cards - Camile requires custom designed I/O cards developed by DOW.
Analog Input, Analog Output, and Digital Input/Output boards are provided.

Performance Characteristics

Scan Rate	Not Mentioned
Alarm Types:	Not Mentioned
Max. Number of Input Devices/Communication Ports:	Maximum of 22 Camile I/O boards per box; software can accommodate two boxes using COM1 and COM2 ports.

Reference: Catalogs provided by Dow, dated Sept. 1991.

CADEPA by FAMIC Automation Inc.

CADEPA incorporates a graphical technique known as Grafset. Grafset is a graphical method for specifying industrial automation and is sometimes referred to as Sequential Function Charts (SFC). CADEPA allows a user to edit a design specification in Grafset format and translates this into code into ladder logic code with full documentation for Allen-Bradley, Siemens, TI, Mondon, GE Fanuc, Square-D, and Idec PLCs.

Basic Platform

IBM XT, AT, PS/2 or compatible
Other platforms available (VMS, UNIX)

Functionality

Statistical Process Control - Not Mentioned

Ladder Logic Control - Ladder logic control is available as described above. Additional software called ALCAD is included that generates fully documented and well structured code which can be transferred to Allen-Bradley or ICOM PLC-5 Ladder programming software.

Networking/Data Input

Not Mentioned

Software Interfacing

Relational Database - Interfacing not mentioned.

Higher Level Software - Not Mentioned

Hardware Interfacing

PLCs -	Allen-Bradley	GE Fanuc	Idec
	Industrial PCs	Modicon	Siemens
	Square-D	Texas Instruments	others

I/O Boards - Not Mentioned

Performance Characteristics

Scan Rate:	Not Mentioned
Alarm Types:	Not Mentioned
Max. Number of Input Devices/Communication Ports:	Not Mentioned

Reference: Catalogs furnished by FAMIC Automation Inc., dated Dec. 1991.

FIXDMACS by Intellution, Inc.

Basic Platform

IBM PC XT, AT, PS/2 (Models 50, 55SX, 60, 70, 80), IBM Industrial Computers (Models 7531, 7552, 7561, 7562) and 100% compatibles running DOS or OS/2
VAX running VMS

Functionality

Statistical Process Control - For FIXDMACS, statistical process control is created by the development of Statistical Control and Statistical Data blocks. Statistical Data blocks can be defined for automatic, manual, or event driven operations. The user can choose auto-calculation on a startup, moving average basis, or the user can input his/her own control limits. Available blocks for SPC include:

Statistical Data - Collects and analyzes data from the database, user-written programs, or manual entry. User written programs allow importing data from other computers and instruments.

Statistical Control - Acts as a supervisory controller, changing control parameters based on statistical data to optimize quality.

In addition, data can be exported to other statistical packages.

Ladder Logic Control - Not Mentioned

Networking/Data Input

PCNet, Token Ring, Ethernet, DECnet, Novell.

Software Interfacing

Relational Database - DMACS files are able to be exported to Oracle, Abstat, Ingres, DBase III, and other programs that accept fixed-length ASCII files.

Higher Level Software - POMS, AS/400 MRP, and other software can be interfaced.

Hardware Interfacing

Over 60 drivers including: Allen-Bradley, Siemens, Analog Devices, Texas Instruments, General Electric, Square-D, and Optimum. In addition, with the advanced I/O driver Tool kit, you can write your own I/O driver for FIX DMACS.

Performance Characteristics

Scan Rate:	1 second - 30 minutes
Alarm Types:	Eight different alarm types are provided.
Max. Number of Input Devices/Communication Ports:	4

Reference: Catalogs provided by Automatic Control Concepts and Personal Evaluation.

SETCON by SETPOINT, Inc.

The basic SETCON product supports real-time control functions as well as data acquisition, data aggregation, and database construction and maintenance capabilities. Layered SETCON products include:

SETCON-Calc	A spreadsheet program with report writing capabilities.
SETCON-SPC	Providing statistical process control
SETCON-Network	Enabling SETCON to exchange data with other systems within the plant or business environment; facilitating systems integration.
SETCON-PC	Allows use of personal computers as control workstations, effectively interfacing the user with SETCON.
SETCON-DCH	Compresses data through specialized techniques in recording control history.

Basic Platform

VAX running VMS

Functionality

Statistical Process Control - SETCON-SPC features X-Bar & R and X-Bar & S charting with histogram support. Attribute data can be presented with p, np, c, and u charts.

Ladder Logic Control - Not Mentioned

Networking/Data Input

SETCON-Network software allows data exchange between SETCON systems operating in multiple VAX/MicroVAX computers running DECnet.

Software Interfacing

Relational Database - Not Mentioned

Higher Level Software - Not Mentioned

Hardware Interfacing

Interfaces are available for connectivity between SETCON and most DCSs or PLCs.

Performance Characteristics

Scan Rate:	Not Mentioned
Alarm Types:	Not Mentioned
Max. Number of Input Devices/Communication Ports:	Not Mentioned

Reference: Catalogs provided by SETPOINT Inc., dated March 1992.

SETCIM by SETPOINT, Inc.

The basic SETCIM product supports real-time, event-driven information systems applications. Data acquisition, database structuring and data maintenance are additional features. Layered SETCIM products include:

SETCIM-Q	Provides statistical process control.
CIM-Calc	An Electronic spreadsheet program.
CIM-Net	Provides data exchange and systems integration capabilities.
GCS	(Graphics Control System) Real-time graphics package that provides the control system operator with real-time information on unit operations. Used in conjunction with SETCON or SETCIM.
CIM-AB	Provides an interface between SETCIM and Allen-Bradley PLC-2, PLC-3, and PLC-5 controllers.

Basic Platform

SETCIM runs on the full line of Hewlett-Packard PA-RISC computers under HP-UX and DEC VAX computers under VMS and DEC's RISC-based Ultrix systems.

GCS runs on MS-DOS PCs, DEC VAX stations under VMS, DEC stations under Ultrix and Hewlett-Packard PA-RISC computers.

Functionality

Statistical Process Control - CIM-Q features X-Bar & R charting with histogram support. Attribute data can be presented with X-Bar, p, np, c, and u charts.

Ladder Logic Control - Not Mentioned

Networking/Data Input

SETCIM-Network supports the DECnet network for DEC VAX computers and Hewlett-Packard's LAN/9000 link for Ethernet (LAN) using HP 9000 series computers.

Software Interfacing

Relational Database - Not Mentioned.

Higher Level Software - Not Mentioned

Hardware Interfacing

Interfacing with PLCs and I/O boards is available.

Performance Characteristics

Scan Rate:	Not Mentioned
Alarm Types:	Not Mentioned
Max. Number of Input Devices/Communication Ports:	Not Mentioned

Reference: Catalogs provided by SETPOINT, Inc., dated March 1992.

Glossary

DCS: Distributed Control System

DECnet: A communications network developed by the Digital Corporation.

Ethernet: A communications protocol established by the IEEE 802.3 standard.

I/O: Input/Output

Ladder Logic Control: Refers to a functionality within the software to generate or modify a Ladder Logic

Diagram. The diagram could be down loaded to a PLC or run on the PC.

LAN: Local Area Network

MAP: Manufacturing Automation Protocol

MMS: Manufacturing Message Specification

MRP: Material Requirements Planning

PLC: Programmable Logic Controller

POMS: Process Operations Management System (A software marketed by IBM).

SFC: Statistical Process Control

SQL: Structured Query Language

Token Ring: A communications protocol established by the IEEE 802.5.

COMBAT RATION ADVANCED MANUFACTURING TECHNOLOGY DEMONSTRATION (CRAMTD)

Introduction to Bar Coding Technical Working Paper (TWP) 57

**M. Jafari, and J.M. Weber
Rutgers, The State University of New Jersey
July 1992**

**Sponsored by:
DEFENSE LOGISTICS AGENCY
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Alexandria, VA 22304-6145**

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"Introduction to Bar Coding"

Technical Working Paper (TWP) 57

M.A. Jafari and J.M. Weber

Abstract

This technical report describes the current state of the technology of bar coding. A bar code system includes the specific bar code symbology, the method of printing bar codes, the method of reading bar codes, the way the data is collected, and how the components are interfaced. In this report each of these areas are introduced and explained with sufficient detail to give the reader an overall understanding of bar coding.

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General Purpose of the Technical Report

Section 3.4.2 of STP#5 Technical proposal of contract DLA 900-88-0383 between Rutgers University and the Defense Logistics Agency requires the contractor to perform a comprehensive survey of industry on data collection. The purpose of this technical report is to describe the current state of technology on bar coding. This is a working document and is subject to revision.

Introduction to Bar Code

The technology of bar code has been around since the late 1940's. But it has only recently become accepted as being useful in industries other than supermarket applications. Bar code is a useful and effective means to improve productivity and accuracy in any data entry application.

The primary goals of bar code is the reduction of data entry errors and the increase of data entry speed. Bar code is far quicker and far more accurate than a typical key entry operator. Generally, a key entry operator enters data at a rate of two to three characters per second. Bar code data entry rates are often around 30 characters per second. Key entry operators have a typical error rate of one error in every 300 characters. With bar code the error rate can be reduced to one error in every three million characters.

There are a number of different components and considerations that must be taken into account when putting together a bar code system. These components and considerations include the specific bar code symbology that will be used, the method of printing these bar codes, the method of reading these bar codes, the way the data will be collected, and how the components will be interfaced together. In this report each of these areas will be introduced and explained with sufficient detail as to give the reader a good overall understanding of what is out there in bar code.

Bar Code Symbologies.

Bar code symbols usually include a combination of bars and spaces that represent letters and/or numbers. There are a number of different bar code symbologies. A symbology is the specific way that the bars and spaces are laid out to represent the information intended. A bar code is a symbol that should be easily read by a computer and should be relatively easy to produce.

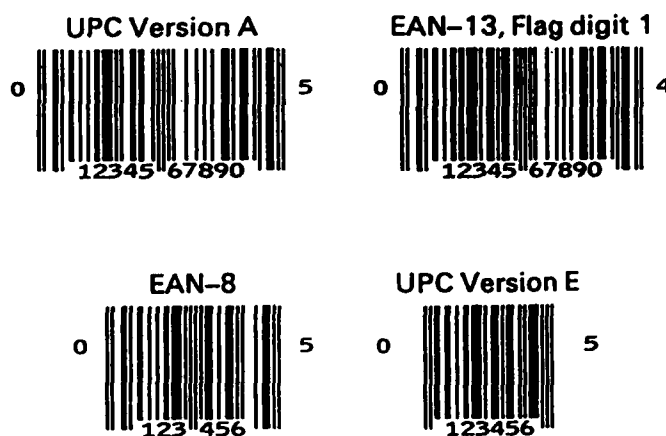
There are two primary categories of bar code symbologies. These are *continuous* or *discrete*. In a discrete bar code individual characters have their own set of bars and spaces, between each character there is a separation space. This separation space is called the *intercharacter gap*. In a continuous bar code there is no intercharacter gap, the entire code has meaning.

Now we will briefly discuss some of the different types of bar code symbologies and where possible we will show a diagram of that type of bar code. All diagrams have been taken from Adams, [2].

Universal Product Code (UPC) and European Article Numbering (EAN)

These codes are basically the same, EAN is a more general symbology. This type of bar code is a continuous code. The specific data storage capacities of the code vary depending on which version is used. The capacities generally range from 12 to 14 digits, although there is one version that can contain as many digits as required.

UPC and EAN are usually used in the grocery industry. Since, UPC is a continuous code with exacting tolerances, it is difficult to print on 'in house' type printing, detailed later. Following is an example of these type of codes:



Samples of UPC and EAN code

Code 39

Code 39 or code 3 of nine is one of the most popular codes for non-retail applications. It has been selected as the official Department of Defense and the Federal government bar code format.

Code 39 is a discrete type symbology, each character having its own set of bars and spaces. This set of bars and spaces is arranged in such a way that each character has nine elements, three of which are wide, hence the name 3 of 9. Characters that can be coded with Code 39 include 10 digits, 26 letters, space, and the symbols -, ., \$, /, +, %.

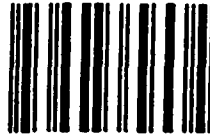
Following is an example of Code 39:



Sample of Code 39

2 OF 5 CODE AND INTERLEAVED 2 OF 5 CODE

This bar code symbology codes all data in the width of the bars. The spaces between the bars carry no data at all. This is a discrete type code. It has found acceptance in many areas. These areas include warehouse inventory, photo finishing, airline ticketing, baggage-handling, and cargo handling.



123456

Sample of 2 of 5 code

Code 128

Code 128 was developed to allow the encoding of the entire ASCII 128-character set. Code 128 is a discrete code where each character consists of 11 elements. Each character is separated by spaces. Code 128 is growing in popularity because of the fact that all characters of the ASCII set can be encoded. Industries where Code 128 is being used include the electronics industry, and the health care industry.



Sample of Code 128

Code 93

Code 93 is similar to Code 39. It was created to provide a higher density of data than Code 39. It is a continuous type symbology. The amount of data that can be stored in the code is limited only by the type of scanner that will be used to read the data.



Example of Code 93

Code 11

Code 11 is a very high density, discrete numeric bar code. It is used by AT&T to identify its telecommunications components and equipment.

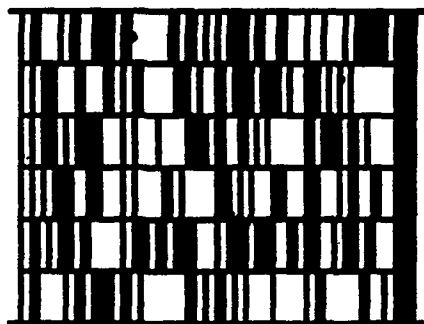


Example of Code 11

As well as the above 'single row' bar code symbologies, meaning that one code only contains one line of data, there are what could be called 'multi-row' bar code symbologies. These symbologies contain a number of lines of data in one symbol. These codes were developed for applications that require a large amount of information to be packed into one symbol. Following are a couple of examples of this type of bar code.

Code 49

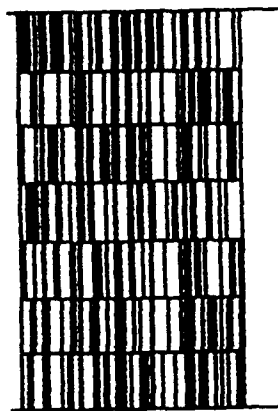
Code 49 is a continuous variable length symbology. Each code can have between two and eight rows of data. Each row is separated by a horizontal bar. This type of bar code can encode the complete ASCII 128-character set.



Example of Code 49

Code 16K

One problem with Code 49 is that it requires a lot of memory to decode the symbol. Code 16K was developed to make decoding of a multi-row bar code easier. Code 16K is a continuous, variable length symbology. Each symbol can have between two and sixteen rows.



Sample of Code 16K

There are many other types of bar code symbologies. The ones presented in this paper are the most popular. For a list of other bar code symbologies currently in use see reference Harmon and Adam [3]. It also provides a comparison between the most popular codes.

Printing of Bar Codes

One of the most important aspects of bar code is the printing of bar codes. You can have the best reading equipment currently produced, but if the quality of bar code printing is very poor the reading equipment will not be able to decode the symbol.

Bar codes can be printed either directly on a product itself, directly on a products packaging, or on labels that can be attached to a product or its packaging by an adhesive backing. When using adhesive labels, there are a number of different surfaces that the bar code can be printed on. These surfaces are referred to as the 'bar code label stock'. Some of these bar code label stocks are: vinyl, paper, metal, and thermal. The different label stocks can come in either continuous-form, meaning many sheets attached end to end, such as dot matrix printer paper, or as discrete-form, such as office copier paper.

There are three primary ways in which bar codes can be printed: commercial printing, off-site label printing, on-site printing. Each individual way of printing has its own advantages and disadvantages.

Commercial Printing

Commercial Printing involves having the bar code printed on the product packaging at the time the packaging graphics are printed. When a bar code is static (meaning it does not change from unit to unit, for all individual units of a product, for example, the UPC code printed on a grocery article) commercial printing is the most economical way of producing the bar code. This method is the most economical because, the bar code is incorporated into the design of the product packaging (that is, there are no additional costs required). With other bar code printing techniques cost(s) for printers, ink, and/or special labels are incurred.

If a product must contain a variable type bar code, such as a serial number, then commercial printing can not easily be used. This is because most commercial printing techniques rely on photographic methods to produce printing plates. These plates are very expensive, therefore it would be quite infeasible to produce an individual plate for each individual product. Although, in some instances, if a discrete bar code symbology

is being used, a sequential type bar code can be added to a package as part of a larger printing process using special number heads in a letter press.

The main advantage of commercial printing is that the quality of the bar code is very good. This leads to fewer errors in decoding the bar code. Another advantage of commercial printing is that, many bar code printing companies have had a number of years experience producing bar codes, therefore the benefit of experience is added to the printing process.

Off-Site Bar Code Label Printing

When variable information must be contained on a bar code off site printing is a good option. Off site label vendors can supply bar codes with variable information on most any type of bar code label stocks. With this type of printing, again, the benefit of an experienced printer is gained. This leads to better quality labels that can be read by the decoding system.

One primary consideration into whether either of the two previously mentioned printing techniques are feasible is if the information to be bar coded is known ahead of time. If the information is known ahead of time and the vendor is quick to respond to demand requirements then some form of off site printing is probably the most feasible. Another aspect that must be taken into consideration is the volume on bar code labels that are required. If it is cheaper to purchase printing equipment and print the bar codes on site then off site printing should not be considered.

On-Site Bar Code Label Printing

The two primary factors that keep on site bar code printing from being used is the cost of purchasing the equipment required and the quality of on site printing. There are a number of printer types that can be used to do on-site label printing each type with its own price range, quality of print, volume/period of print, and type of label stock that can be used on that type of printer. The six most common types of on-site bar code printing are dot matrix impact, laser, thermal, thermal transfer, formed character impact, and ink jet.

Dot Matrix Impact Printing

Dot matrix impact printing is the most popular way of printing bar code labels 'in-house'. Dot matrix printers with bar code capability range in price from a few hundred dollars to a few thousand dollars. The more expensive the printer the faster it prints and the better the over all quality of the bar code.

The main problem with dot matrix printing is the way that printing is done. The bars are made up of a series of dots, this causes the edges of the bars to be jagged. This limits the density of the number of bars per inch. So this type of printing is unsuited for small or dense bar codes.

Dot matrix printing is best used when the density of the bar codes required is low to medium. Dot matrix printers work best with continuous feed type label stocks. Those types of stock best suited for dot matrix printing are vinyl or metal stock.

Laser Printing

Laser printing of bar codes is basically the same as using a laser printer for any other type of application. The quality of a bar code produced on a laser printer is quite good. The range of prices on laser printers is from under \$2000 to as much as over \$13,000.

One problem with laser printers is that they can not use continuous form label stock. As well, certain types of label stock can cause problems with the printer itself. For instance, since the printing path for laser printers is curved, the labels can become unstuck jamming up the printer or causing glue from the back of the labels to become stuck on the printer mechanism.

Another problem with laser printing is that laser printing deposits toner on top of the printed surface. This toner can be scratched off relatively easily, so in an application where the label may be scraped often it is not recommended to use laser printing.

Laser printers can produce a relatively high volume of labels. The printers can print very high to medium density bar codes and can print bar codes requiring complex text and graphics.

Thermal and Thermal Transfer

These methods of printing are relatively similar, they both use heated pins to melt specially coated coverings on label stock to produce a printed label. In thermal printing, the pins heat chemicals on the covering of label stock. These chemicals change color when heated. In thermal transfer printing, heated pins melt a waxy coating on label stock. When this waxy coating is melted a pigment contained in the waxy coating is flowed onto the paper.

This type of printing is one of the least expensive printing techniques. The price of thermal printing units is only slightly higher than the price of dot matrix printers. These printers can print medium density labels at rates up to 10 labels per minute

Formed Character Impact

Formed character impact printing is the printing method originally preferred by LOGMARS (the Department of Defense group that established the military's bar code standard) when they first printed a report on the most cost effective way to produce bar codes. Today it is not the most cost effective. Formed character impact printing works in much the same way as a typewriter. A certain symbology is broken up into individual characters, the code for each individual character is etched into a typewriter type print head. When that character is needed a carbon ribbon comes between the print head and the label stock, the print head then strikes the ribbon leaving the symbol on the label stock. The problem with this type of printing is, it can only do discrete bar code symbologies.

This type of printing method can produce good quality high to medium density labels at a rate of about 100 per minute. These printers are more expensive than dot matrix or thermal printing systems, they are in the same price range as laser printers.

Ink Jet

An ink jet printer squirts drops of from a nozzle onto a print surface. When this type of printing is used with bar coding the bar code is made up of dots of ink. These printers are much more expensive than any of the other types of printers. The benefit they offer is, in some applications data can be coded directly onto products moving on a conveyer belt. This eliminates the cost on label stock.

There are two types of ink jet printers, high-density and low-density. High-density printers can print about 100 labels per minute on continuous-form label stock. Low density ink jet printers are designed for applications such as that detailed in the previous paragraph.

Types of Bar Code Readers

A bar code is read by sweeping a small spot of light across the bar code symbol. A sensor inside of a bar code scanner deciphers the patterns of light and dark and converts that pattern to an electrical signal. A computer then translates this electrical signal into the data that was contained on the printed bar code label.

There are three primary types of bar code scanners, the contact wand, the active noncontact scanner, and the passive noncontact scanner. As well for each type of bar code scanner there exists hand held portable versions of each.

Contact Wands

Contact wands are the most popular scanner presently used to decode bar code. These scanners resemble a pen. To read the printed bar code the tip of the wand is moved across the entire symbol. Inside the tip of the wand there is a light emitter and a light detector. Since the operator manually does the scanning, there are no moving parts contained in wand scanners. These scanners are relatively inexpensive, lightweight, and durable.

The main problem with this type of reader is, the tip of the wand must be placed directly over the printed symbol. The reader can not read at a distance. Following is an example picture of a contact wand.



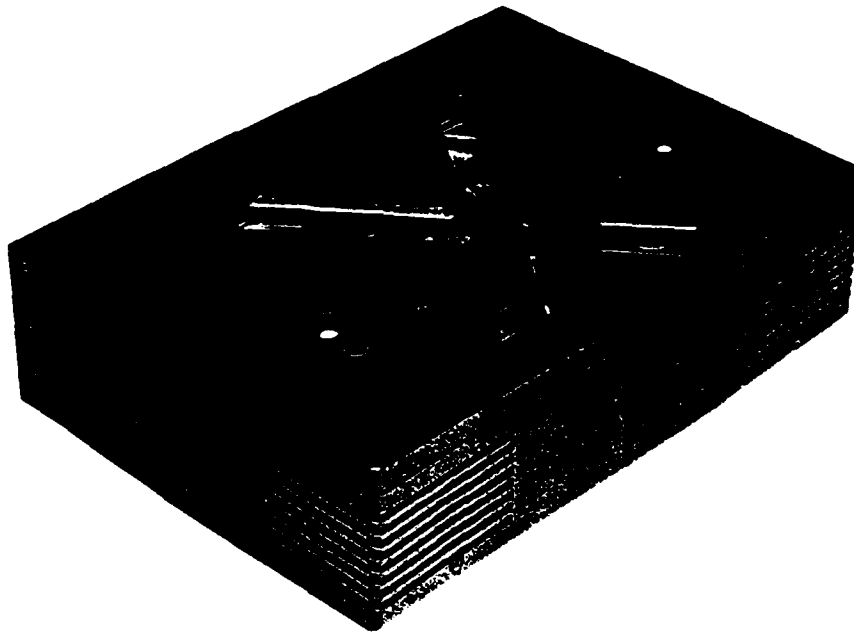
Example of a contact wand.[2]

Noncontact Readers

Noncontact readers are able to read bar codes at a distance. Noncontact readers are gaining wide popularity. If it is difficult or impossible to use a wand to perform a reading function then in some applications a noncontact reader is the only choice.

Active Noncontact Readers

Active noncontact readers generally use laser light as the light source for reading bar code symbols. These readers require either the reader or the bar code to be moved such that the focused beam of light goes across the whole symbol. The scanners found in grocery stores is an example of an active noncontact reader.



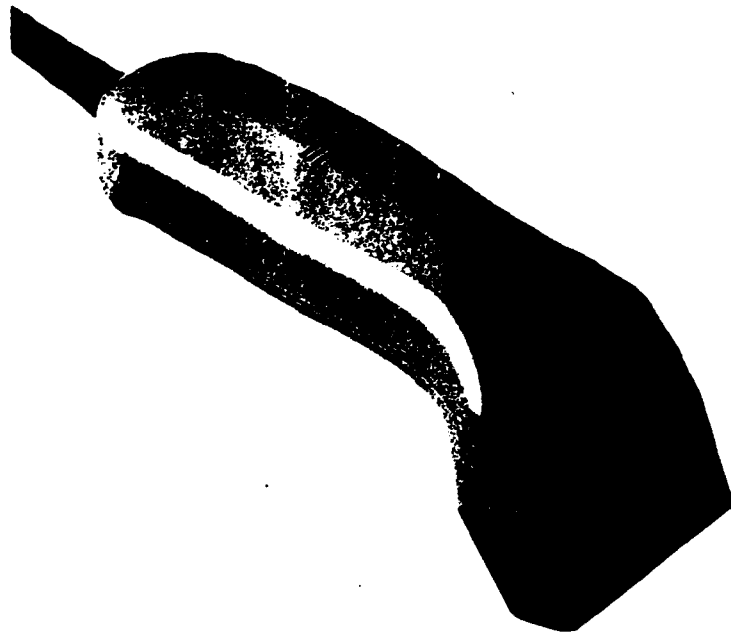
Example active noncontact reader.

This is the type of reader used in grocery stores.[2]

Passive Noncontact Readers

Passive noncontact readers operate like a video camera. The bar code is illuminated by a photo flash or by floodlights. The image of the bar code is focused onto an array of photo detectors contained in the reader. These type of readers require no physical movement of the reader or of the printed bar code.

The following is a picture of an example passive noncontact reader.



Example of a passive noncontact reader.[2]

Visible-Light Laser Diode Scanners

Lasers have been used in bar code scanners since early 1986. Initially the lasers used were He-Ne based lasers. In the late 1980's a new laser technology emerged. This technology is visible laser diodes (VLD). VLD are more power efficient than the He-Ne predecessors. These VLD scanners are growing in popularity quickly.

Portable Bar Code Readers

Portable bar code readers allow the physical connection between reader and computer to be broken. The different types of portable bar code readers are as varied as the applications that require them. Whether the application calls for a printer, a multi-line display, or a specific type of scanner, they are all out there.

One aspect that must be taken into consideration when using portable bar code readers is the cutting of real time link to mainframe computer operations. If bar coding is used in a large manufacturing system some data may need to be known instantly, for instance when a special part arrives in receiving. When using portable bar code readers the information that a specific part was in would not be made available until the data contained in the reader was down loaded at the end of the day. One way to over come this problem is to use wireless communication. The problem with wireless communication is that there are a number of Federal Communication Commission (FCC) regulations that must be followed.

General Bar Code Reader Information

For each of these types of bar code readers there are a number of different 'platforms' that they can be used in. By 'platform' we mean the different ways a scanner can be configured, i.e. hand held, stationary, wireless. Hand held bar code scanners are those scanners that can fit easily in the human hand. Stationary scanners are those scanners that are fixed in place. With stationary scanners the area to be read, for example a product serial number, is passed through the field of vision for the scanner. Wireless scanners are those scanners that are not tied continuously and directly to a host computer. Wireless scanners can use radio waves to connect to a host machine, or they can be down loaded when needed. For just about any 'platform' desired, there are scanners that utilize all of the different scanning technologies described above.

Interface Considerations

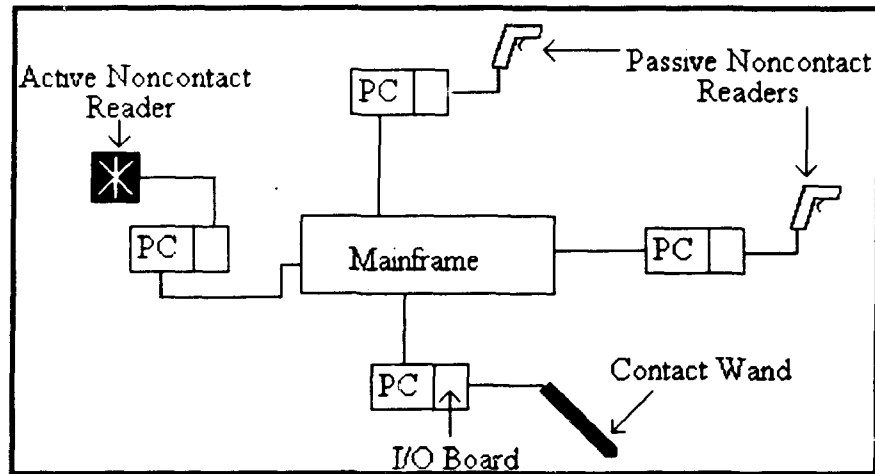
Once a bar code symbol has been read the data contained on that bar code must be taken and placed somewhere where it can be made use of. This place is usually a mainframe computer system. The reason that mainframes are usually the place where bar code data is sent to is that most of the time bar code applications are very large, they require many different data collection points and often times produce large amounts of data. These multiple site and data volume requirements are often too large to be handled by a PC. Also the data received from a bar code system is often used in bigger applications such as a Management Information System which is usually contained on a mainframe. Although, for small applications it is possible to interface with a PC via a device called a WEDGE. A wedge is a piece of hardware that is connected to a computer. Bar code readers can be connected to a wedge. The wedge then interprets the bar code signal and passes the data on to the microprocessor as if the data were entered using a keyboard.

Once the data has been passed to a host machine the data is processed however is necessary. Personal Computers (PC's) can be used to receive the data from a bar code reader, but then the PC would be interfaced into a mainframe so that the mainframe can do the actual data manipulation.

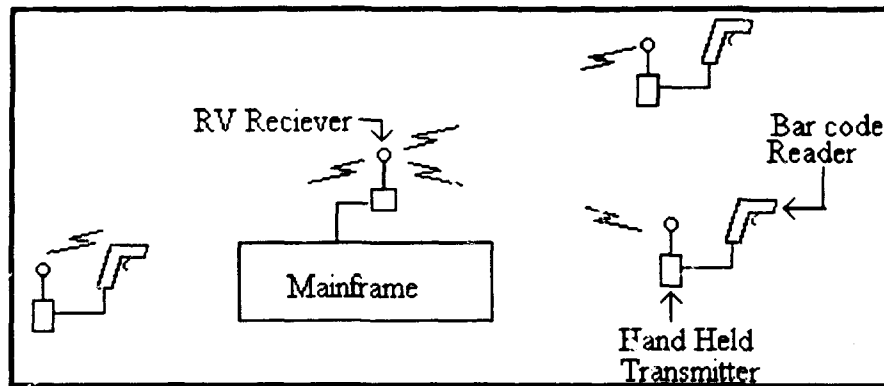
When interfacing from a reader to a computer there are a number of ways that the electronic signal from the reader can be deciphered by a computer. There are stand alone devices that interpret the electronic signal into its ASCII equivalent then sends the ASCII equivalent to a host computer. Also, software exists that can be run on both PC and mainframe that interprets a readers signal directly.

When interfacing different pieces of equipment the standard protocols and interface connections exist, i.e. RS-232, RS-232C, RS-422, RS-449, and RS-485.

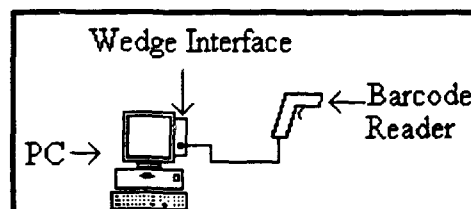
Following are some figures on possible interfacing architectures.



Sample Multinode Bar code System Architecture



Sample Wireless Bar code System Architecture



Sample Wedge interface Architecture

General Bar Code Information

This article is written to give the reader a basic understanding of 'what is out there' in the world of bar codeing. For a more indepth analysis of the topics presented in this paper the book by Adams[2] is excellent. The book prvides data on scanning rates, accuracy, power requirements, and much more.

Glossary of Terms[2]

automatic data collection: Automatic data collection includes any system or device for inputting information into a computer system without a human acting as an intermediary between the source of the data and the input device.

bar code: An array of rectangular bars and spaces that are arranged in a predetermined pattern following unambiguous rules to represent elements of data that are referred to as characters.

bar code label: A label that carries a bar code and, optionally, other human readable information; it can be affixed to an article.

bar code reader: A device used to identify and decode a bar code symbol.

bar code symbol: A graphic code, either printed or photographically reproduced, composed of parallel bars and spaces of various widths. A bar code symbol contains a leading quiet zone, a start character, one or more data characters (including in some cases a check character), a stop character, and a trailing quiet zone.

continuous code: A bar code in which the space between two characters is part of the code.

discrete code: A bar code symbol in which the spacing between characters is not part of the code, and can vary within wide tolerances.

noncontact reader/scanner: A bar code reader typified by fixed- or moving-beam scanners that can scan and decode a bar code symbol without making contact with the symbol.

symbol: A symbol is something that represents something else by association, resemblance, or convention.

sympology: Representation or expression by means of a symbol.

variable-length code: A code that can be of any length within a range of lengths. The length of the bar code only depends on the data encoded.

VLD: Visible laser diode. A semiconductor laser that produces light between 670 and 680 nm, which is within the visible light spectrum.

wedge/wedge reader: A bar code reader designed to fit in-line between a keyboard and a computer or CRT. The keyboard is plugged into the wedge and a cable from the wedge is plugged into the keyboard interface on the computer or CRT. Data scanned using a wedge appears as if the data were typed into the computer or CRT, eliminating the need to modify application software.

Bibliography

- [1] *Automatic ID. News*, Advanstar Communications, Inc. Volume 8 no 3.
March 1992.

- [2] **Sourcebook of Automatic Identification and Data Collection**, Adams, R.
Van Nostrand Reinhold, New York. © 1990, pg. 1 - 84.

- [3] **Reading Between the Lines**, Adams, R. and Harmon, C.
Helmets Publishing, NH © 1989, pg 32

Appendix A

Company Addresses[2]

Commercial Printing

Film Master Sources

Bar Code Associates
PO Box 9542
Alexandria, VA 22304
(703) 823-3737
(800) 368-2737

Bureau of Engraving, Inc.
500 S. Fourth St.
Minneapolis, MN 55415
(800) 328-4960

Computype, Inc.
2285 W. County Road C
St Paul, MN 55113-2567
(800) 328-0852

GGX Associates, Inc.
11 Middle Neck Road
Great Neck, NY 11021
(516) 487-6370

Graphic Technology, Inc.
14824 W. 117th Street
Olathe, KS 66062-9304
(913) 829-8000

Photographic Sciences Corporation
770 Basket Road
Webster, NY 14580
(716) 265-1600

Preprinted Barcode Label Printing

Computype, Inc.
2285 W. County Road C.
St. Paul, MN 55113-2567
(800) 328-0852

Precision Photography, Inc.
1150 N. Tustin Ave.
Anaheim, CA 92807
(714) 632-9000

RJS Enterprises
140 E. Chestnut
Monrovia, CA 91016
(818) 357-9781
(800) 331-0793

R.J. Mindlin and Associates
270 Regency Ridge, Ren. Bldg. Ste 106
Dayton, OH 45459
(513) 435-3406

Symbology, Inc.
PO Box 13262
Roseville, MN 55113
(612) 631-0520

Western Publishing Company, Inc.
510 Highway 175
O'Fallon, MO 63366
(314) 272-7820

Metalcraft, Inc.
149 4th Street S.W.
Mason City, Ia 50401
(800) 437-5283

Data Compsistions, Inc.
1099 Essex
Richmond, CA 94801-2185
(800) 227-2121

Data Documents, Inc.
3403 Dan Morton Dr.
Dallas, TX 75236
(214) 296-0567

Data Documents Systems, Inc.
301 Gardner Dr.
Industrial Airport, KS 66031
(800) 722-7295

Dennison Manufacturing Company
300 Howard Street
Framingham, MA 01701
(617) 879-0511

Graphic Technology, Inc.
14824 W. 117th Street
Olathe, KS 66062
(913) 829-8000

Horizon Research Inc.
Codemark Division
18531 S. Miles
Cleveland, OH 44128
(216) 475-8500

VLD Bar Code Readers

Metrologic Instruments
143 Harding Ave.
Bellmawr, NJ 08031
(609) 933-0100

Opticon Inc.
36 Ramland Rd.
Orangeburg, NY 10962
(914) 365-0090

The Pannier Corp.
207 Sandusky ST.
Pittsburgh, PA 15212
(412) 323-4900

W.H. Brady Company
Industrial Products Division
2221 W. Camden Rd.
Milwaukee, WI 53201
(414) 351-6630

Watson Label Products
Label Division
3684 Forest Park Blvd.
St. Louis, MO 63108
(314) 652-6715

Western Publishing Company, Inc.
510 Highway 175
O'Fallon, MO 63366
(314) 272-7820

York Tape and Label Company
1953 Stanton Street
York, PA 17405
(717) 846-4840

Photographic Sciences Corp (PCS)
770 Basket Rd.
Webster, NY 14580

Symbol Technologies, Inc.
116 Wilbur
Bohemia, NY 11716-3300
(516) 563-2400

Tohken Co. Ltd.
5 Hutton Center Dr., Ste 690
Santa Ana, CA 92707
(714) 641-6811

Thermal Printer Retailers

Monarch Marking Systems
(800) 263-4650

COMBAT RATION ADVANCED MANUFACTURING TECHNOLOGY DEMONSTRATION (CRAMTD)

**A Survey and Evaluation of Existing Production
Planning and Control Software
Technical Working Paper (TWP) 64**

**M.A. Jafari, T. Altiok and J. Pan
Department of Industrial Engineering
Rutgers, The State University of New Jersey
March 1993**

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1.0 GENERAL:

Purpose of the Technical Report

Section 3.4.2 of STP#5 Technical Proposal of contract DLA 900-88-0383 between Rutgers University and the Defense Logistics Agency requires the contractor to perform a comprehensive survey of industry for the existing software on production planning and inventory control. The purpose of this technical report is to describe the important features of these software packages. It also describes our evaluation of these products. This is a working document and is subject to revision.

In the report, we describe thirteen software packages (see Table 1) on production planning and inventory control. For each package, we describe the hardware requirements and functionality. The information has been obtained through software demonstration and/or from the literature provided by the software vendors or distributors.

In section 2.0, we give our evaluation. Sections 3.0 and 4.0 , respectively, have the software overview and functional overview of each software product. In the appendix, we provide a glossary of the technical terms used in the report.

2.0 SOFTWARE EVALUATION

In an earlier report (TWP #51), we defined four classes of manufacturing related functions. These classes are business functions, manufacturing planning functions, product development functions, and manufacturing control functions. The class of business functions include accounting, sales forecasting, product costing, pricing and sales, order processing, and purchasing. The class of manufacturing planning functions include aggregate production planning, materials requirement planning, and production planning. The class of product development functions include formula management and maintenance. The class of manufacturing control functions include materials management and control, quality management, factory floor scheduling, shop floor control, and maintenance management. See TWP#51 for more detail description of these functions and their requirements specification.

In this section we shall briefly analyze the different features of the surveyed software according to our classification of the manufacturing functions. In sections 3 and 4, we shall describe these features in more detail.

Table 1

1. BUSINESS 400	8. MIMI
2. CIMPRO	9. PRISM
3. FACTOR	10. PROBE
4. FACTORIAL	11. Q-CIM
5. G2	12. SCHEDULEX
6. MAPS	13. SEI
7. MICRO-MRP	

We shall start with Business 400. Except for quality management, this software offers many of the different functions in the classes of manufacturing planning and manufacturing control. It also offers some functions in the product development and business functions classes. The software runs on IBM AS/400 which is a mid range computer. CIMPRO offers many different functions in all four classes. It is based on relational data base technology and runs on a wide range of computers. FACTOR offers some functions on manufacturing planning and control classes. But its main functions are simulation and analyzing "what if" scenarios. Similarly, FACTORIAL offers some functions in the manufacturing planning and manufacturing control classes. As far as business and product development functions are concerned, both software fail to offer any major functionality. Both software can run on a PC environment. G2 offers some major functions in manufacturing control and some in manufacturing planning. As far as decision making tasks are concerned, this software seems to be quite powerful. However, it does not offer any functions in the business or product development classes. MAPS offers functions mostly related to manufacturing planning and some functions related to business. It runs on mid range computers with cut down version running on a PC environment. MICRO-MRP offers some functions in the class of manufacturing planning and some in business class. It can run on a PC environment. MIMI is developed around a data base with functions mostly in manufacturing planning and control classes. It also uses expert system technology and can be interfaced to SQL based data bases. It does not offer any functionality in product development or business classes. PRISM functionality very much relates to manufacturing planning and control, and business

classes. It can run on PC as well as mid range computers. PROBE offers functions related to all four classes. It runs on any platform supporting UNIX operating system. Q-CIM offers some functions in each class. It can run on a PC environment. SCHEDULEX provides functions in the manufacturing planning and control classes. One major feature is its finite capacity scheduling. SEI provides functions on manufacturing planning and control, and business classes. It runs on mid range computers.

In the software requirements specification given in TWP#51, we have considered flexibility and open structure as desirable characteristics for some of the functions. Our observation is that, in general, the surveyed software packages lack these properties to a very large extent. In fact, to use any of these packages for a given application requires some tailoring which is often done by the personnel of the software vendor or distributor.

3.0 SOFTWARE OVERVIEW:

1. BUSINESS 400

The software is written using RPG/400 language, and is native to AS/400. It provides such functions as tele-sales, warehouse control, financial manager, service management, scheduling, sales analysis, inventory management, purchase management, master production scheduling, MRP, CRP, shop floor data collection, order entry, production control and costing. The Business 400 Accounts Receivable application maintains customer information such as Customer accounts, Customer status and Customer credit information. The Accounts Payable application keeps track of all suppliers information. The General Ledger takes journal from Business 400 application or user defined system. The Sale Order Processing application takes care of different types of orders from different locations (i.e. sales office, warehouse). It also provides administration costs for sales management. The Tele-sales application supports sales staff with Customer call profiles which contains the information of which operator should make the call, the contact they should ask for, the list of items to be sold and the frequency and timing of the call. The Sales Analysis application provides a database of sales and order information within a business organization. The sales history database can be defined by users and it can include item analysis, customer analysis, sales budget information, order information etc. The Inventory Management application can be used to provide stock planning. It can also be used together with Forecasting and Master Production Scheduling applications for production planning. The Forecasting application

uses long term or medium term history to predict demand. There are seven standard forecast formulas available and new formulas can be added. The Purchase Management application is used to control purchase orders. It provides a Supplier database to control orders quality. Such database contains information as which supplier provides the best price of an item. The Warehouse application is used to control warehouse activities. The Distribution Requirements Planning application provides key information for planning and control of the company's distribution activities. The Production Database Management and Standard Costing application provide Manufacturing System information such as manufacturing methods, machines, resources and operations tools. Therefore, Bill of Material and operational routings can be created and maintained. The Master Production Scheduling application allows material planners to create plans for manufacturing and purchasing. The planner can use item number and planner code from any inquiry screen to plan MRP. The Production Control and Actual Costing application provides control on shop-floor activities. It also provides information on the current status of each work order and work center. The Shop Floor Data Collection application allows the on-line shop-floor data collection, where communication adapters are not needed. A total of 225 terminals can be attached for data collection. The Capacity Planning application plans the work load of each machine at any work station. It can also be installed in job shop to control work in process.

Hardware Requirements: IBM AS/400.

Vendor/ Distributor: JBA International, 1830 Underwood Dr., Delran, NJ 08075. TEL: (609) 764-1300. FAX:(609) 764-9792.

2. CIMPRO

The software provides such functions as data collection, forecasting and sales analysis, order processing, production/quality/inventory control, and capacity planning. It can also integrate planning and scheduling with process simulation, process data, and PLC. Data conversion is available when sales analysis files are moved from one computer system to another. The CIMPRO Formula Management application allows users to use different units of measure at any step of the process. For each product, multiple formula, yield calculations for theoretical vs. actual yield, and product testing are available. It also controls the critical data of production by simulation. Questions like "where ingredients A and B are used together in the same formula?" can be answered. Once the formula is created for a production item,

Product Costing application automatically calculates cost for intermediate or finished goods. The Laboratory Decision Support application can change the combination of ingredients for a product according to customer or market requirements. The Regulatory Compliance application is used to handle the reporting and labeling procedures demanded by government regulations. The safety properties associated with a product is generated by CIMPRO Material Safety Data for appropriate safety maintenance. The Inventory Management application provides information and control of warehousing and lot location. The Production Management application controls production process by batch or continuous flow. It also provides on-line shortage checking before issuing the production order to the plant. The production analysis includes expected and actual yield by batch/production run, as well as the expected /actual costs. On-line lot tracking inquiries are available for ingredient, intermediate, rework material and finished goods. The Process Operation Control application keeps track of a batch of production at each step of the manufacturing process. The start and completion times are recorded for material staging, ingredient measurement, quality testing, set-up, production and clean-up. The Quality Management application tracks and maintains quality specification and actual test results for raw materials, intermediates and finished goods. Information is kept in a central data base for ease access and reporting. The Master Production Scheduling application provides a view of high level demand and converts these demands directly into planned or released production. Multiple shipping schedules supports shipping information by day or weeks. The primary function of Process/Material Requirements Planning application is to analyze live data of purchase order, scheduled batches and batch in progress. These data can then be used for production planning. P/MRP uses Just-in-time to purchase order. The order planning and lot sizing decisions are based on the following rules: lot for lot, reorder point rule(minimum/safety stock), economic order quantity and not-planned by P/MRP (scheduled manually by user). The Process/Capacity Requirements Planning application uses plant resources routings and work centers to define available capacity and provides production managers the means to manage physical resources and human resources. The Sales Forecasting application provides an estimate for the sales demands of an item. Users can define a weighted factor for the forecast, then the forecast can be calculated using a least squares method with seasonality and trend analysis. The process of Forecasting is based on sales history, which is collected by the Order Processing module. The Order Processing

application could provide information to the entire manufacturing system. It manages pricing (quantity discounts) for each customer. The Sales Analysis application provides sales history. They are displayed or printed by individual order or line item, and are sorted by range of product, customer, or salesperson for different kind of time range(months). The Purchasing application provides on-line, real-time information access such as purchase material demand, customer orders and sales forecast. It also suggests the optimal purchasing quantity for each item. Once an order is placed, stock information is displayed for Total On Hand, Total On Order, and Total Committed to meet current demand. Invoices are entered in real-time and on-line to Accounts Payable. It controls the out going cash flow and tracks project expenditures. The General Ledger application provides on-line accounting support.

Hardware Requirements: A wide range of computers.

Vendor/Distributor: Datalogix International, Inc., 100 Summit Lake Dr., Valhalla, New York 10595, TEL:(914) 747-2900

3. FACTOR:

The software provides simulation-based decision support and does off-line finite capacity planning and scheduling. It is a management tool for short- and long-term simulation of manufacturing systems. It simulates the production floor, and answers "what if" questions on the factory floor. FACTOR provides on-line shop floor information access such as materials and personnel. The software contains Scheduler's Interface, Data Loaders, Multiple Alternative Management, Order management, Production Calendar, Shift Scheduler, Resource Maintenance, Schedule Generation, Resources and Resource Group management, Process Planning, Parts and Materials (Raw Material and Sub-assemblies) management, Prescheduled Order management, and Reporting. The Scheduler's Interface contains all functions required for production scheduling. The Moduler's Interface lets the user run all FACTOR's functions such as data downloading and reporting, model execution, performance reports, histogram and production schedules. The Data Loaders application loads data into the system for production scheduling. The Order management application is used to manage orders and display the current location of orders on the shop floor such as current operation, operation status, and remaining processing time. The Production Calendar application provides production calendar information and shows when the production facility will be completed off shift. The Shift Schedulers application defines production

operations and resource availability. The Resource and User Maintenance application lets the user to schedule preventative maintenance or incorporate breakdowns into schedule generation to determinate their impact. It also allows loading of maintenance schedules from other systems. The Schedule Generation application allows multiple execution runs of production scenarios. The Resources and Resource Groups application allows users to select the appropriate resources. The Parts application displays detailed information on parts such as part number, part families and subfamilies, production cost information, and value-added tracking. The Raw Materials and Sub-assemblies application displays item status by the production process and tracks cost data on all workpieces. The Process Plan application defines item movement through production process. The Pre-scheduled Orders application allows user-defined resources reservation for specific orders and schedules the remaining production process for these orders. The Report and Schedules application provides performance reports, comparison reports, and production schedules.

Hardware Requirements: DEC VAX, HP 9000 Series 800 Precision Architecture System, IBM 370, IBM compatible PC's with OS/2. I/O Ports to other hardware are addressed upon user request.

Vendor/Distributor: Pritsker Corporation, Suite 500, 8910 Purdue Rd., Indianapolis, Indiana 46268,

TEL:(317) 879-1011. FAX: (317) 879-0500.

4. FACTORIAL:

The system is written using C and runs on OS/2. It does on-line tracking, collects data, manages resources, controls inventory and quality, and provides process planning and scheduling. The WorkFlow Manager application provides on-line tracking, data collection, resource management, inventory status, configuration management, lot tracking, etc. It also allows on-line event-driven work flow control. The Material Services application provides Just-in-time material control, material movement control and inventory accounting through the entire production process. Min/Max inventory levels can be calculated by user-defined and pre-defined determinant factors. This application also provides on-line display of the status and location of materials in WIP. The Labor Services application provides on-line display of labor status and tracks requested, refused, accepted and worked overtime. It also

provides user-configurable or site-specific cost accounting and payroll requirements for service and manufacturing requirements. The Quality Services application provides statistical analysis and display, based on the data collection performed by WorkFlow Manager. The Link-Gateway application allows on-line communication with other applications.

Hardware Requirements: PS/2..

Vendor/Distributor: Factorial System, Inc., 6300 Bridgepoint Parkway, Suite 350, Austin, TX 78730, TEL:(512) 345-1192, FAX:(512) 345-1238.

5. G2

G2 is a real time expert system. There are many application software products developed around G2 technology. The family of G2 products can be used for monitoring, controlling and scheduling production processes, on-line fault analysis and intelligent alarming, statistical and expert quality control, and process start-up and shut-down. G2 also provides off-line simulation and monitoring, operator training, process and plant-wide optimization.

Using the expert system technology, it is possible to do dynamic finite capacity scheduling. The dynamic feature of this function refers to its capability of rescheduling the production when some drastic changes occur in the system. It is also possible to build a knowledge base using the expertise of the plant personnel and use it toward on line production optimization. Through a graphical interface and using expert system technology together with a library of filters, mathematical and statistical functions it is possible to do real time process control and monitoring. G2 also provides a platform for rapid prototyping and simulation of a system operation. There are also bridge products that provide interfacing to a wide range of third party software products, e.g., relational data bases, and PLC programming environments.

Hardware Requirements: DEC VAX stations and DEC stations, HP 9000/ and 9000/8xx workstations, SUN 3 and SUN 4 workstations, TI Explorer and micro Explorer, Symbolic 36xx series, Apple Macintosh II, Apollo, and 386 machines.

Vendor/Distributor: Gensym Corporation, 125 Cambridge Park Dr., Cambridge, MA 02140, TEL:(617) 547-9606, FAX:(617) 547-1962.

6. MAPS:

The system is designed to manage plant operation. It is an on-line, menu-driven system combining order entry, MRP, CRP, standard product costing, master scheduling, shop floor and inventory control, and accounting. The Order Entry application provides control of customer orders such as initial orders, changed orders, picking and partial or complete shipping. The Product Database application manages required data for production process. The data base stores data for engineering, production, inventory control, and costing. The Master Production Scheduling application produces a schedule for each product and schedules all production activities. This application also computes parts requirements based on forecasted demand for finished goods. The Material Requirements Planning application determinates all the necessary materials for the "build schedule" and tracks materials on-hand and order quantities to arrive at new requirements for each level. The Standard Product Costing application maintains cost information for materials and labor. It also calculates and updates set up, variable overhead, and fixed overhead. The Shop Floor & Inventory Control application performs order release, shop floor control and inventory control. The Capacity Requirement Planning application provides information of current records of labor and machines utilization, and analyzes the work loads. This application also allows users to track the production processes. The Financial application manages Accounts Receivable, Accounts Payable, Inventory and General Ledger.

Hardware Requirements: mid range computers such as AS/400. Cut down version for PCs on Novell networks.

Vendor/Distributor: M&C Systems Inc., Bethany Commons at Hazlet, 1 Bethany Rd., Suite 49, Hazlet, NJ 07730, TEL:(908) 739-9080, FAX:(908) 739-6993.

7. MICRO-MRP:

This is an MRP II software system intended to control the manufacturing operation. The software runs on IBM and compatible microcomputers. It provided such functions as order processing, quality, inventory control, material and capacity requirements planning and scheduling. The Bill of Materials application provides on-line control over purchased or manufactured parts and calculates standard costs using "cost rollup" logic. The Inventory Control application tracks and maintains inventory balances for raw materials, components,

assemblies, and finished goods. This application also displays or prints inventory information, by part and by order number. On-line warning messages alert user to out-of-tolerance or exception situation. The Master Scheduler application maintains forecast and master schedule on-line and uses user-defined resources to plan work hours, capital, or workcenter requirements (rough cut capacity planning). The Materials Requirements Planning application balances the demand and supply for all part components needed to meet the Master Schedule requirements. The Purchase Control application creates and prints purchase orders, tracks purchased materials, maintains vendor information, and predicts cash requirements. The Sales Order Entry application provides on-line real-time customer orders and on-hand inventory data. This application also tracks company sales performance and provides information for future forecasting. The Shop Floor Control application can be used to create shop orders, tracks work-in-process (WIP), maintains workcenter information, and analyzes shortages and backlogs. The Costing application controls cost variance information for parts, shop orders, purchased orders, and stockrooms. The Management Performance application examines vendor performance, manufacturing performance and inventory performance. The Configurator application allows feature/option configuration for a part to satisfy customers requirements. The Repetitive Manufacturing application allows manufacturing to produce finished products by entering the parent part number, quantity completed, and the date of completion.

Hardware Requirements: IBM PC's or IBM compatibles, Hewlett-Packard 9000 series.

Vendor/Distributor: Micro-MRP Inc., Century Plaza 1, 1st floor, 1065 East Hillsdale Blvd., Foster City, CA 94404, TEL:(415) 345-6000, FAX:(415) 345-3079.

8. MIMI:

The system has its own database to provide efficient, transportable processing of computationally intensive planning and scheduling functions. The software is used in conjunction with an MRP II system to provide information on scheduling and planning . It can make direct generic links to certain SQL based databases. It can also integrate planing and scheduling functions with process data and process simulation models. The MIMI/MJ application is a module for planning and scheduling batch or discrete manufacturing facilities. This application also generates production schedules which consider finite production capacity, sequence dependent setup costs, alternative operations, precedence

relationships, and inventory requirements. The MIMI/E application provides heuristic or expert system capabilities to assist in the formulation and solution of planning and scheduling problems.

Hardware Requirements: IBM, DEC, HP and other Micro, Mini, and Mainframe computers under several operating systems including DEC's VMS; IBM's VM/CMS, MVS/TSO, OS/2 and AIX; XENIX; and other operating systems with a full "C" compiler.

Vendor/Distributor: Chesapeake Decision Sciences, Inc., 200 South Street, New Providence, New Jersey 07974, TEL:(908) 464-8300.

9. PRISM:

The system is designed for process planning and control. The software provides such functions as yield calculation, scheduling, resource planning, production analysis, purchasing, accounting, order management, and capacity management. The Resources Management application defines and manages all manufacturing resources. The Production Analysis application provides user-defined analysis of yield rates, downtime, scrap, substitutions, waste, efficiency, and utilization for each production process. The Resource Planning application plans manufacturing resource requirements such as MRP and CRP. The Advanced Costing application provides product costing tools which allows users to apply daily spending to production. The Purchase application manages the procurement cycle. The Customer Order Management application controls the order processing cycle, allowing customer services representatives to quickly enter orders. It also calculates price of each order using user-defined pricing schemes. The General Ledger, Accounts Payable and Accounts Receivable applications control vendors and customers information.

Hardware Requirements: IBM system AS/400 & system/386

Vendor/Distributor: Marcam Corporation, 95 Wells Ave., Newton, MA 02159, TEL:(617) 965-0220, FAX:(617) 965-7273.

10. PROBE(SIP 3000):

The system consists of the following modules: order entry, formula management, inventory management, accounts receivable/payable, sales management and analysis, purchasing and receiving and general ledger. SIP is an on-line system where detailed transaction is kept by the system for as long as the user requires it. SIP provides on-line financial information for

any period of time. The software package is used in five different foreign languages. The Inventory Management application provides information of inventory items, warehouse inventory status, vendor prices, and selling prices. The Customer Order Entry application handles customer orders, inquiries and order history. It also provides on-line customer credit checking and telephone order entry. The Purchasing and Receiving application provides on-line tracking of the entire purchasing process and the finished goods shipment status. The Requisitioning application tracks quotes from vendors and allows entry of internal requisitions for goods. The Formula Management application controls the production process and allows users to try out different possible variations of user-defined formulas without effecting live data. The Sales Management and Analysis application maintains on-line sales projections and planning, supporting a continuous ongoing comparison of the plan with actual sales figures. It also provides sales history and on-line sales inquiry, and allows manual sales entry. The Accounts Receivable and Account Payable applications handle all transactions related to customers' and vendors' accounts. Invoices created by Customer Order Entry application is automatically entered as new sales on account to Accounts Receivable, then automatically posted to the General Ledger. It also allows on-line selection of vendor invoices for payment, tracks outstanding vendor invoices, and assists prompt payment of bills. The General Ledger application provides an on-line display of company's financial situation, and on-line account inquiry.

Hardware Requirements: any hardware running UNIX operating system.

Vendor/Distributor: Probe Software, Ltd., 601 Ridge Ave., Evanston, IL 60202, TEL:(312) 866-7732.

11.0-CIM:

This is a process planning and scheduling package with such functions as inventory management, quality management, order processing, and production control. It is written in ANSI 85 COBOL. The Quality and Specifications application provides automatic Quality Control approval against product or customer specifications, and supports specific checking for raw material, working in process, and finished goods. The Order Management application provides information of order pricing and discounting, user-defined inventory allocation or selection, stock reservation, and shipment qualification. The Materials Management application provides inventory control, packaging alternatives, inventory

reconciliation, and yield management. The Bill of Materials application provides multiple bill types and on-line "where-used" function. The Material Requirements Planning application handles master scheduling and shop calendars. It also provides on-line planning data access. The Master Production Scheduling provides rough cut capacity checking, updates material planning, and generates "what-if" simulation results. The Capacity Requirements Planning application provide capacity planning and production modeling based on Just-in-time logic, and models system with "what-if" capability. The Event Generated Costing application allows "what-if" analysis, and reports cost variance of actual vs. standard.

Hardware Requirements: Hewlett-Packard MPE/XL HP 3000, network minicomputers, PC's.

Vendor/Distributor: Q-CIM Development Laboratories Inc., 5 Independence Way, Princeton, New Jersey 08540, TEL:(609) 987-9696.

12. SCHEDULEX:

The system provides finite medium to long range capacity planning and scheduling for process manufacturing. The system can be integrated with other functions such as MRP, Forecasting and Process Control. The software is used in conjunction with MRP II to provide material planning under finite capacity constraints. Schedulex provides information on deciding which products should be made on which production lines, in which quantities, and in which sequence. It also uses Just-In-Time for alternative schedules.

Hardware Requirements: PC (IBM PS/2 model 70's), HP-3000, HP-9000, IBM system/386

Vendor/Distributor: Numetrix Inc., 401 Merit 7, Norwalk, Connecticut 06851, TEL:(203) 847-3452, FAX:(203) 846-3537.

13. SEI:

The system has such functions as general ledger and financial reporting, accounts payable, payroll, purchasing, fixed assets, maintenance management, food packing, and production management.

The Production Management application provides order processing capability(order entry and release), production planning (based on historical demand and forecast sales), production scheduling, and production analysis. The Maintenance Management application

controls inventory in spare parts, tracks estimated vs. actual usage for each defined equipment unit, provides Work Order Schedules using traditional calendar, designs manpower analysis for manpower productivity optimization, and keeps a complete maintenance history for the life of the equipments. The SEI's Food Distribution system provides an accounting system for the wholesale food distributor or processor/distributor. The system contains three functions: Order Processing, Accounts Receivable and Inventory Management. The Order Processing application provides customer, shipping, order, and salesman information. The SEI's Food Packing, Processing and Distribution system provides accounting system for the wholesale food packer/distributor or processor/distributor. The system contains three functions: Order Processing, Accounts Receivable and Inventory Management.

Hardware Requirements: UNIX, all models of IBM RISC system/6000. Written in Business BASIC.

Vendor/Distributor: Stoltz Enterprises Inc., 1515 Poydras St., Suite 1750, New Orleans, Louisiana 70112, TEL:(504) 588-1000.

4.0 FUNCTIONAL OVERVIEW:

This section includes a detail breakdown of functions in each software. (*) is used when the literature provided by the vendor or distributor clearly specifies that function. (?) is used when it is implicitly mentioned in the literature or it is implied somehow. If (*) or (?) is not used then we are not certain whether or not the software contains such a functionality.

	C I M P R O	G 2	M I M I	S C H E D U L E X	P R I S M	P R O B E	Q C I M	S E I
1. Production Planning								
1.1 Forecasting and Sales Analysis	*					*		
1.1.1 Simulation	*							
1.1.2 Sales Analysis	*					*	*	*
1.2 MRP	*		*	*	*		*	
1.2.1 Manual Planning	*			*				
1.2.2 Simulation Capability	*		*	*				
1.3 Master Prod. Scheduling	*		*	*			*	*
1.3.1 Multiple Shipping Scheduling	*		*				*	
1.3.2 Generates "What-if" Simulation Results	*		*	*			*	
1.4 CRP	*		*	*	*		*	
1.4.1 Primary and Secondary Resource Planning	*		?		*			?
1.5 Modeling and Analysis:	*	*	*	*	*	?	*	
1.5.1 Just-In-Time Scheduling	*		*	*	*		*	
1.5.2 Dynamic Rescheduling	?	*	*					
1.5.3 Expected and Actual Yield (by Batch)	*					?		*
1.5.4 Expected and Actual Cost	*							

	C I M P R O	G 2	M I M I	S C H E D U L E X	P R I S M	P R O B E	Q C I M	S E I
1.5.5 Standard Production	*				*			?
Analysis Inquiry and Report								
2. Production Management								
2.1 Packing and Repacking of Bulk Material	*							
2.2 Batch Production History	*				?	*	*	*
2.3 Production control	*	*	*	*	*			*
2.3.1 Cycle Time Analysis	*	?						
2.3.2 Multiple Resource Reporting per Step	*		?		*			?
3. Inventory Management:								
3.1 Lot Control	*				*	*	*	*
3.2 Unit Measure Conversion	*				*		*	?
3.3 Inventory Location	*				*	*	*	*
3.4 Yield Management	?	?			*		*	*
3.5 Item Stock Inquiry	*				?	*	*	?
4. Formula Management :								
4.1 Rework Material	*							
4.2 Multiple Formulas	*					*		
4.3 Product Testing	*					?		

	C I M P R O	G 2	M I M I	S C H E D U L E X	P R I S M	P R O B E	Q C I M	S E I
4.4 Where-used Inquiry	*						*	
4.5 Packaging(Bulk Prod.)	*							
4.6 Formula Costing	*					*		
4.7 What-if Formula Analysis	*					*		
5. Product Costing :								
5.1 Pull Key Cost Out of the Pool of Overhead Dollars					*			?
5.2 Multiple Cost Variance	*				*	*	*	
5.3 Distribution of Actual Overhead to Actual Production	*				*	?	?	*
5.4 Detailed Prod. Cost at Batch Level	*			?	?	?	?	*
6. Laboratory Decision Support *								
7. Regulatory Compliance	*						*	
8. Quality Management								
8.1 Customer-specific Quality Requirements	*	?			?	?	?	
8.2 Quality Information Tracking by Batch/Lot of Production	*	?			*		*	

	C I M P R O	G 2	M I M I	S C H E D U L E X	P R I S M	P R O B E	Q C I M	S E I
9. Maintenance Management								
9.1 Actual Usage	*				?			*
9.2 Auto Scheduling	*		?		?			*
9.3 Equipment Number	?				?			*
9.4 Planning	*		*		*			*
9.5 Parts Replacement	?							*
10. Purchasing	*				*	*	*	*
11. General Ledger	*				*	*		*
12. Order Processing/Mgmt								
12.1 Customer Information	*				*	*		*
12.2 Pricing Simulation	*				*	*	?	*
12.3 Order Entry	*				*	*	*	*
12.4 Shipping Entry	*				*	*	*	
13. Interfacing with Other Hardware & Software								
13.1 Bar Coding	*						*	
13.2 Generic SOL Interface			*					
13.3 Supervisory Control	*						*	
13.4 Corporate Planning System	*			?	?			
13.5 Corporate Financial System	*				?			

	C I M P R O	G 2	M I M I	S C H E D U L E X	P R I S M	P R O B E	Q C I M	S E I
13.6 Corporate Customer Service System	*				?			
13.7 MRP				*				
13.8 Forecasting				*				

	B U S I N E S S 400	M A P S	M I C R O M R P	F A C T O R	F A C T O R I A L
1. Production Planning					
1.1 Forecasting and Sales Analysis	*		*		
1.1.1 Simulation	?				
1.1.2 Sales Analysis	*	*			
1.2 MRP	*	*	*	*	*
1.2.1 Manual Planning					
1.2.2 Simulation Capability		?			
1.3 Master Prod. Scheduling	*	*	*	*	?
1.3.1 Multiple Shipping Scheduling					?
1.3.2 Generates "What-if"			*	*	
Simulation Results					
1.4 CRP	*	*	*	*	*
1.4.1 Primary and Secondary	?	*	*	?	?
Resource Planning					
1.5. Modeling and Analysis:			*	?	?
1.5.1 Just-In-Time Scheduling.					?
1.5.2 Dynamic Rescheduling			*		?
1.5.3 Expected and Actual Yield (by Batch)					
1.5.4 Expected and Actual Cost	*		*		
1.5.5 Standard Production	?		?		
Analysis Inquiry and Report					

	B	M	M	F	F
	U	A	I	A	A
	S	P	C	C	C
	I	S	R	T	T
	N		O	O	O
	E		.	R	R
	S		M		I
	S		R		A
	400		P		L

2. Production Management

2.1 Packing and Repacking
of Bulk Material

2.2 Batch Production History ? * ?

2.3 Production Control * * * ?

2.3.1 Cycle Time Analysis ? ?

2.3.2 Multiple Resource * ?
Reporting per Step

3. Inventory Management:

3.1 Lot Control * ? ? ? *

3.2 Unit Measure Conversion.

3.3 Inventory Location * ? ? * *

3.4 Yield Management ?

3.5 Item Stock Inquiry * ? * *

4. Formula Management :

4.1 Rework Material

4.2 Multiple Formulas ?

4.3 Product Testing

4.4 Where-used Inquiry *

4.5 Packaging (Bulk Prod.)

4.6 Formula Costing ?

	B U S I N E S S 400	M A P S	M I C R O M R P	F A C T O R	F A C T O R I A L
<hr/>					
4.7 What-if Formula Analysis					
<hr/>					
5. Product Costing :					
<hr/>					
5.1 Pull Key Cost Out of the Pool of Overhead Dollars					
<hr/>					
5.2 Multiple Cost Variance	*	*	*		
<hr/>					
5.3 Distribution of Actual Overhead to Actual Production	?	?	?		?
<hr/>					
5.4 Detailed Production Cost at Batch Level		?	?	*	
<hr/>					
6. Laboratory Decision Support					
<hr/>					
7. Regulatory Compliance					
<hr/>					
8. Quality Management					
<hr/>					
8.1 Customer-specific Quality Requirements					
<hr/>					
8.2 Quality Information Tracking by Batch/Lot of Production					*
<hr/>					
9. Maintenance Management					
<hr/>					
9.1 Actual Usage	*		*		
<hr/>					

9.2 Auto Scheduling	*		*	?	?
9.3 Equipment Number	?				?
9.4 Planning	?	?	?	?	?
9.5 Parts Replacement				?	
10. Purchasing					
	*	*	*		
11. General Ledger					
	*	*			?
12. Order Processing/Mgmt					
12.1. Customer Information	*		*		
12.2. Pricing Simulation	*		?		
12.3 Order Entry	*	*	*	*	
12.4 Shipping Entry	*	*	?		
13. Interfacing with Other Hardware & Software					
13.1 Bar Coding	*				
13.2 Generic SQL Interface					
13.3 Supervisory Control				*	*
13.4 Corporate Planning System				*	
13.5 Corporate Financial System	*	*	*	*	*
13.6 Corporate Customer Service System					
13.7 CAD/CAM			*		*
13.8 MRP					*

Appendix

Glossary

1.1 Forecasting and Sales Analysis

Forecasting provides a rolling projection of anticipated sales demand for each product or item class (CIMPRO).

1.1.1 Simulation

Reviews all items required to complete the forecast (CIMPRO).

1.1.2 Sales Analysis

Produces reports to aid market study and analysis based on actual sales and projections. It performs detailed historical analysis by a number of different parameters (PROBE).

1.2 MRP: Material Requirement Planning

1.2.1 Manual Planning

This function will allow the plan to exclude specific items in the planning; it is scheduled manually by the Operator (CIMPRO).

1.2.2 Simulation Capability

Takes a planned order and then projects requirement needs. Multiple forecast versions are simulated to help the planner to predict where and when material shortages will occur (CIMPRO).

1.3 Master Production Scheduling

System allows the user to convert orders recommended by MRP into either firm planned orders or actual batch production order (CIMPRO).

1.3.1 Multiple Shipping

The system supports multiple shipping schedules to satisfy user service requirement (CIMPRO).

1.3.2 Generates "What-if" Simulation Results

1.4 CRP : Capacity Requirements Planning

1.4.1 Primary and Secondary Resource Planning

Plans primary as well as secondary resources. A machine can be planned as a primary resource; personal as secondary resource. If necessary, budget dollars become another secondary resource (CIMPRO).

1.5 Modeling and Analysis

Production Analysis provides user-defined analysis of yield, rates, downtime, scrap, substitutions, waste, efficiency, utilization, and more (PRISM).

1.5.1 Just-In-Time Scheduling

Production analysis is done under the Just-In-Time scheduling.

1.5.2 Dynamic Rescheduling

Production analysis is done under dynamic rescheduling.

1.5.3 Expected and Actual Yield (by Batch)

Analysis of expected yield vs. actual yield.

1.5.4 Expected and Actual Cost

Analysis expected vs. actual cost.

1.5.5 Standard Production Analysis Inquiry and Report

Standard production analysis inquiries and reports include:

Ingredient where-used in batch; scheduled ingredient requirements; production activity report; lot usage - inquiry by product; lot disposition inquiry; ingredient usage history; display batch history and cost; critical inventory reports; work in progress (WIP) inventory (CIMPRO).

2. Production Management

Decides which products to be produced and when, keeps track of parts and material during the production cycle, reports what quantities are produced (CIMPRO).

2.1 Packing and Repacking of Bulk Material

Allows maximum flexibility in deciding how bulk material is to be packaged as part of the production flow or as a separate step (CIMPRO).

2.2 Batch Production History

Integration of production with lot tractability is essential for full lot tracking required by governmental agencies. It allows user to maintain an unlimited number of batch runs for historical purposes. Information is maintained for costing, performance, and quality decisions into the future (CIMPRO).

2.3 Production Control

Tracks a batch of production through each step of the manufacturing process. As the production batch moves through the production area, actual yields, scrap and rework are reported at each process step and compared to expected yields (CIMPRO).

2.3.1 Cycle Time Analysis

Starting and completion times are recorded for the various events that occur within a process center at each step: material staging, ingredient measurement, quality testing, set-up, production, and clean-up (CIMPRO).

2.3.2 Multiple Resource Reporting per Step

Tracks all of the resource components at the processing step. The actual amount of set-up, production, and clean-up time for each resource is tracked against the standard time allocated for the resource to come up with a comparison between actual and standard resource cost (CIMPRO).

3. Inventory Management

3.1 Lot Control

Tracking and tracing any product by lot, or any ingredient that have its lot identity recorded (CIMPRO).

3.2 Unit of Measure Conversion

Users are allowed to use all different kind of units of measure, and conversions are made automatically (PRISM).

3.3 Inventory Location

Manage multiple stock locations and multiple warehouse location (PRISM).

3.4 Yield Management

Uses these user-defined yields for analysis (PRISM).

3.5 Item Stock Inquiry

On-hand/ committed package information at product, warehouse and lot level are available (CIMPRO).

4. Formula Management

4.1 Rework Material

Rework material with the same item number can be factored into the process at different steps (CIMPRO).

4.2 Multiple Formulas

Multiple formulas for the same product are allowed (CIMPRO).

4.3 Product Testing

Test criteria in production, implying adjustments required to meet the desired, ever- changing characteristics of ingredients and products are available (CIMPRO).

4.4 Where-used Inquiry

Sophisticated "where-used" inquiry answers questions such as, "where are ingredients A and B used together in the same formula? (CIMPRO). Also lists materials which are **not** used/active in any formula (PROBE).

4.5 Packaging(Bulk Products)

Accommodates traditional methods of defining packaging material on a formula or separate list. Flexibly defines generic pack types (CIMPRO).

4.6 Formula Costing

Screen will show the actual cost , the market replacement cost , and the forecasted future cost of an inquiry material (PROBE).

4.7 What-if Formula Analysis

It analyzes the formula costs when formulas are changed (PROBE).

5. Product Costing

Cost is developed as part of the procedure of defining and producing product. The module calculates and tracks costs, and in preparing price lists - with provisions for material, labor, overhead and other user-defined cost accumulations (CIMPRO).

5.1 Pull Key Cost Out of the Pool of Overhead Dollars

This feature gives the user a more accurate picture of the profit contribution of each product, and each product line, permitting more informed decisions (PRISM).

5.2 Multiple Cost Variance

It can develop multiple variances within one period (e.g., usage variances for last month) or cost variance between periods (e.g., last month to frozen standards, last month to last quarter)(PRISM).

5.3 Distribution of Actual Overhead to Actual Production

The costing module takes activity-based costing and uses the user defined rules to determine distribution of actual overhead to actual production (PRISM).

5.4 Detailed Product Cost at Batch Level

Batch cost history display provides summarized production details (CIMPRO).

6. Laboratory Decision Support

LDS provides an interactive spreadsheet that determines key characteristics of the formulated products (solid weight percent, specific gravity, etc.), and allows formulators to manipulate the formulation to determine what combinations of ingredients can meet a formulated product specification. LDS provides interactive "what if" capability in determining formulated product characteristics, based on the ingredient technical data, and formula quantity relationship (CIMPRO).

7. Regulatory Compliance

Provides SARA (Superfine Amendments and Reauthorization Act) reporting capability in sections of emergency planning and release, right to know, and toxic chemical release to comply government regulations requirement (CIMPRO).

8. Quality Management

It is designed to track and maintain quality specifications and actual test results for raw materials, intermediates, and finished goods (CIMPRO).

8.1 Customer-Specific Quality Requirements

Order Entry allows review of unique customer specifications, and the commitment of the lots of finished goods that meet those specifications. Customer-specific requirements are tracked down to the customer "ship to" location. As new items are added to inventory, many related parameters are created for each item by assigning it to a designated class (CIMPRO).

8.2 Quality Information Tracking by Batch/Lot of Production

Quality information is tracked for each batch/lot of production. Information includes: ingredient specification, manufacturing parameters and specific quality control test results and instructions (CIMPRO).

9. Maintenance Management

9.1 Actual Usage

Entry of actual resource usage and labor requirements allows for estimate/actual comparison to aid in more definitive procedure definition (SEI).

9.2 Auto Scheduling

Auto scheduling of preventive maintenance based on usage or time frame uniquely defined for each piece of equipment (SEI).

9.3 Equipment Number

Coding structure allows for equipment to be defined by plant area, unit, assembly (machine) and part # (SEI).

9.4 Planning

Work order planning eliminates the duplication of procedure steps and/or excess resource estimation (SEI).

9.5 Parts Replacement

Tracks of replaced parts for failure and replacement prior to failure (SEI).

10. Purchasing

Provides the tools needed to manage the procurement cycle. Purchasing automates tedious, clerical procurement functions, allowing buyers to concentrate on vendor management (PRISM).

11. General Ledger

12. Order Processing/Management

Responses to customer inquiries about order status, or places new order, or modifies existing orders and invoices, inventory or reports (CIMPRO).

12.1 Customer Information

Within each customer record, the following information are maintained: multiple ship-to location, order items, user-defined scheduling, credit limit, shipping method, delinquency payment indicator, etc. (CIMPRO).

12.2 Pricing Simulation

Allows quick access to customer and production pricing for quotation or analysis (CIMPRO).

12.3 Order Entry

12.4 Shipping Entry

It is used by the shipping department to record exactly what was filled, how many, backordered, etc. The Bill of Landing may be selected individually for each shipment for a select range of orders (PROBE).

**Review of
FIXDMACSTM v2.1 for DOS
and
FIXDMACSTM for WindowsTM**

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FIXDMACS Review

1. Introduction

The purpose of this report is to review the capabilities of the FIXDMACS v2.1 for DOS and FIXDMACS for Windows software. We will focus on the following areas: hardware requirements, interfacing, setting up an application, and networking. We will also present some application examples.

2. Hardware Requirements

FIXDMACS can be run on a stand alone PC, on a Local Area Network (LAN), or on a mainframe setup. Possible operating systems that can be used are DOS, OS/2, or VMS. In the DOS environment, packages are available to run either straight in DOS or through Microsoft® Windows™ 3.1.

FIXDMACS v2.1 requires at least 20MB free hard disk space. FIXDMACS for windows requires 60MB of free hard disk space. A stand alone DOS node requires 2MB of RAM. A distributed DOS node requires 3MB of RAM. A Windows node, stand alone or distributed requires a minimum of 8MB of RAM. FIXDMACS uses EMS (Expanded Memory Storage) which makes non-DOS memory available to DOS for running programs and storing data. To optimize memory usage FIXDMACS requires the use of an Expanded Memory Manager™, such as Quarter-deck Expanded Memory Manager (QEMM). FIXDMACS also requires that a math coprocessor be installed in any machine running FIXDMACS.

3. Interfacing

3.1 Software Interfacing

FIXDMACS can be interfaced to any relational database that adheres to SQL standards. This link is accomplished through the use of an add on SQL interface module. This interface provides a two-way, real-time link between FIXDMACS and a relational database.

Another available add-on module is "C database and Historical Data Access." This module provides the user with the ability to gain access to the FIXDMACS process database via Microsoft C programs. This supplies the user with access to real-time and historical plant floor data. This allows for customized analysis and control.

Additionally, FIXDMACS for windows can be directly interfaced to any external program using the Dynamic Data Exchange (DDE) Interface protocol for Windows. This allows FIXDMACS to share data with DDE-compatible programs, such as Microsoft Excel or Lotus123 for Windows. This provides the capability of generating real time graphs and reports in standard spreadsheet or word processing applications.

3.2 Data Acquisition

FIXDMACS can be interfaced directly with both I/O boards, and Programmable Logical Controllers (PLC's) for the purpose of Data Acquisition. The software drivers for most major I/O boards and PLC controller cards are written by the manufacturer of FIXDMACS. This is important because if there is a problem with the driver the person who wrote the driver can be contacted directly through the manufacturer of FIXDMACS.

4. Setting up an Application

4.1 The Database

The first step in using FIXDMACS is to design a control "database". This database is not a data storage type database, rather, it is used to define such things as what information is to be obtained, where it is to be obtained from, what calculations must be performed, what control actions should be taken, how often operations should be done, and what values of data will cause the alarming mechanism to be set off.

This database is created using a number of generic "blocks". Each block performs a specific function. Some of the available blocks are; Analog Input, Analog Output, Digital Input, Digital Output, Calculation, Program, Trend, Statistical, Histogram, PID, and On/Off control. These blocks are linked together into chains. One database may have many chains. Once the control database has been created views are then drawn.

To a user who has familiarized him/herself with the creation of a database, via a couple of easy examples, creating a database for almost any application is not an extremely involved task. The hardest part of the database design process is defining the "rules" of how the real system is going to operate. Once the operations of the real system, and FIXDMACS's role within the system, have been defined, designing the database is a relatively easy task.

4.2 Display Screens

When drawing a display, there are two drawing options that can be used to add features to the display, objects can be either free drawn, or linked to the process control database. The links to the database are what provide FIXDMACS with control of a process. There are a

number of possible links. Some of these links are Value, Color, Graph, Trend, Control, Sub-picture, and New display. Displays can be edited pixel by pixel. This allows for a very high degree of visual accuracy in display design. The disadvantage of this is that drawing pixel by pixel is time consuming. Another feature offered by FIXDMACS is animation. Animation is achieved by using the sub-picture link. One problem with this feature is that the user has to draw many displays; one display for each movement. FIXDMACS for Windows does not have this problem. With the Windows version, the user only has to draw the displays at its initial position, then simply move the cursor (or mouse) to the display final position. The software will take care of the middle steps. Currently, a pre-defined library of drawings such as pumps or valves, does not exist for FIXDMACS for Windows. Therefore, the user has to draw all the display symbols needed from the ground up. There is, however, third party software available that contains libraries of pre-defined symbols.

4.3 Alarming

One of the functions of the FIXDMACS package is alarming. In the database, while defining blocks, the designer can specify certain conditions/limits that will set off an alarm, sound and/or color, to let the operator know that a limit has been reached. A feature of the alarming system is the alarm history window. This window displays the last 20 or so alarm messages that were sent to the Scan Control and Alarm function of the software. This allows the user to look at this window to see if there were multiple alarms set off, as well, it gives the operator an idea as to how the operation has been running.

Alarming with FIXDMACS is very easy. The definition of alarms is done when the

database is created. The user is prompted for all required information for each alarm. The alarms are made active simply by running the alarm function from the main options menu.

4.4 Statistical Process Control

FIXDMACS is able to perform Statistical Process Control functions. It is possible to use the software to do SPC charting and alarming on real-time process data. Available control charts are X-bar, Range, Standard Deviation (S-bar), and X-bar with specification limits. Each chart has its own type of limit lines. The X-bar control chart has upper/lower control limits and warning limits. The Range and S-bar control charts have upper/lower control limits. The X-bar with specification limits control chart has upper/lower control limits and specification limits. Also, histograms are available for displaying the density of ranges of occurrence for process values.

Alarms can be set to go off for just about any value of interest with respect to SPC, i.e. the value of: x-bar, any control limit, the standard deviation, a trend, and the range of value.

The statistical functions are relatively easy to use. There are two steps required to use the statistical functions. First, a statistical block is defined in the internal database to collect data on a certain desired value. This value can be an input, and output, or a calculated value. Next, a graph link is created between the internal database and a display screen. After these two steps have been completed the software takes care of all computations necessary. When defining the statistical block and the graph link, the software prompts the user for all required information.

4.5 Historical Trending

FIXDMACS has two additional options that allow data to be historically archived. The first option is historical trending. This option provides the system user with the ability to visualize and chart system parameters over any desired point. This option could be useful for a supervisor who wants to be able to come in at any time and see what a process has been doing over an extended period of time.

The second type of historical archiving is the scheduler option. This option gives the user the ability to, at regular intervals, save the value of any inputs, outputs, or calculations to a file. This file contains all of the values collected. This allows the data to be used by external programs, such as C based programs, to perform a variety of tasks such as statistical analysis. The only problem with this is that when the analysis is being done the data is not the most current.

The historical options are a little harder to use than the other options described until now. This is because the historical options are additional modules external to the basic internal database and displays. While they were not extremely difficult to use, it did take a couple of easy examples to fully understand how these options operated.

4.6 The SIM Driver

FIXDMACS offers a simulation (SIM) driver. This driver allows the system designer to test a system without actually having it set up to real I/O's. This option allows screen design to be tested "off-line."

4.7 Summary of Steps to Create an Application

- Step 1. Allocate expected number of each type of block to be used in application database.
- Step 2. Name the database.
- Step 3. Create/modify database, link Blocks into functional chains.
- Step 4. Draw/modify displays.
- Step 5. Define links between displays and the desired database.
- Step 6. Use SIM to simulate model (optional).
- Step 7. Make required adjustments (i.e. return to step 3).
- Step 8. Run application "on-line."

5. Networking

In general, there are three different types of distributed network architecture; Database Duplication, Send/Receive Tables, and Data Transfer Based on Demand. With Database Duplication, an internal database structure is duplicated between all machines on the network. This tends to cause inefficient use of machine memory. The reason for this is that the database structure which is placed on each machine is an "over all" structure. This structure contains all the database pieces required by each machine individually. So there will be some pieces of the database that each individual machine will not need or use. Therefore, there is useless information being stored on each machine and this wastes memory. Also, if the database needs to be updated or revised at all the change must be made to every machine on the network. Depending on the size of the system this can be quite a tedious task.

Send/Receive tables are tables that tell a software package on an individual machine what

information to pick from each machine on the network. One of the primary problems with this is that, generally speaking, it is very difficult to vary these tables. For this reason a system designer must take into consideration which machines might have/need data for future application changes. These potential swaps of data need to be programmed into the tables when the application is first written. Another problem with Send/Receive tables is that the network traffic tends to be very heavy. This is because the data required by these tables is polled off the network each scan period even if the data has not changed.

The basic concept of Data Transfer on Demand is send only the data needed by each machine when it is needed. With this type of architecture each machine has its own internal database that contains information on the data that is needed for which machine. Also, data is only sent on the network when its value changes, minimizing the network traffic. This tends to be the most efficient architecture design.

FIXDMACS utilizes Data Transfer on Demand. The way that the system designer indicates to the software which information to get from which machine is very simple. Each machine is given a node name. Within each node, specific data is given a tag name. Within each tag, if there is more than one data value of interest, a value name is specified. So to get any single piece of data required from the network, all that must be done is to specify the node:tag:value of that piece of data. The software takes care of retrieving that piece of data when it is needed.

FIXDMACS supports the following network drivers: PCNet, Token Ring, Ethernet, DECnet and Novell.

6. Examples Tried

6.1 The Tank

In order to test and evaluate FIXDMACS two scenarios were tested. The first scenario dealt with a 100 gallon tank filled with water. The tank had a valve above flowing into the tank and a valve below flowing out of the tank. The top valve flowed at a rate of 2 gallons per second, and the bottom valve flowed at a rate of 1 gallon per second. This process was tested using the SIM driver. Alarm limits were set as follows:

LOLO -	10 Gallons
LO -	20 Gallons
OK -	21-79 Gallons
HI -	80 Gallons
HIHI -	90 Gallons

The valves were set such that initially the tank level was 50 gallons, and both valves were open. When the HI alarm was set off the top valve closed and the bottom valve stayed open, causing the level in the tank to *decrease* by 1 gallon per second. When the LO alarm was sounded the top valve was opened again and the bottom valve stayed open, causing the level in the tank to *increase* by 1 gallon per second. From here the process started over again.

The database for this process was relatively easy. It contained a Digital Output block for each valve, an Analog Input block and an Analog Output block for the level of the tank, a Program block, a Trend block, a Calculation block, and a Statistical block. The Calculation block was used to calculate the level of the tank, since this was just a simulation not connected to an actual system. The level of the tank was varied in relation to the state of the top valve.

If the top valve was open the level in the tank increased. If the top valve was closed the level in the tank decreased. The Program block controlled the position of the valves, open or closed, based on the level of the tank.

The display for this process had links to the database for the following: a Trend graph, a picture of the tank, Color links to show the state of the valves (green for open, and red for closed), and new screen options for Alarm History and an X-bar chart. The display was very easy to create. When a link is created the user is prompted to specify such things as size of the link, position of the link, database block that the link is attached to, the value desired, and the color of the link display for different values of the link.

6.2 The Saw

To test FIXDMACS's ability to interface with a PLC we tried an example using a saw and a clamp. There were four control inputs into the PLC:

- | | | |
|----|----------------------|--|
| 1) | Push Button 0(PB0) - | When this button was pushed the clamp was placed down on a piece of wood and a light pressure (20psi) was applied. |
| 2) | Push Button 1(PB1) - | When this button was pushed a heavier pressure (80psi) was applied to the work piece and the cutting cycle for the saw was initiated. |
| 3) | Increase Speed - | When this button was changed from logical 0 to logical 1 the PLC was programmed to increase the rotary speed of the saw by one (1) unit. |
| 4) | Decrease Speed - | When this button was changed from logical 0 to logical 1 the PLC was programmed to decrease the rotary speed of the saw by one (1) unit. |

The database for this example was a little bit more involved than the one for the previous example. Each signal that was an input to the PLC (an output from FIXDMACS) was given a Digital Output block. Each signal that was an output from the PLC (an input into FIXDMACS) was given a Digital Input block. There were a couple of Program blocks and Calculation blocks, used to control the animation of the display.

The display for this example contained relatively few items. It consists of value links for all PLC inputs, color links for the sources of air pressure for the clamp, and a sub-picture link for the saw. The sub-picture for the saw was the most difficult aspect of the display. In order to animate the saw a drawing had to be made for each position that the saw would be in. For this example that entailed 22 drawings. Once the main sub-picture was drawn, drawing each successive movement of the saw involved cut and paste operations, which tends to get rather tedious.

This example used the PLC for its source of control. The sub-picture display and the color links for the valves were set to change when the PLC outputs changed.

7. Conclusion

FIXDMACS is a very robust software. Once two main concepts are understood, creating the database and creating a display, the package is relatively easy to use. The additional capabilities of Statistical Process Control, SQL database access, C database access, Alarming, and Historical Trending make this package useful for just about any automation application.

In all, one of the nicest features offered by FIXDMACS is its help function. If there is ever a question about what type of input a prompted field is looking for, i.e. when creating

database blocks, and links, the user just has to type a "?" and the software offers a list of acceptable entries to that field.

The documentation for this package is alright. While it does contain some flaws, in terms of clearly explaining some aspects, the documentation is written well enough to provide the user with answers to just about any question that could arise. When the documentation does not explain something clear enough, the technical support provided by the software manufacturer can make any clarifications in a timely manner.

Overall, the quality of this package is very good.

**Review of
ONSPEC 1000™**

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ONSPEC Review

1. Introduction

The purpose of this report is to review the capabilities of the ONSPEC 1000 software for OS/2. We will focus on the following areas: hardware requirements, interfacing, setting up an application, and networking. We will also present some application examples.

2. Hardware Requirements

ONSPEC can be run on a stand alone PC, on a local Area Network (LAN), or on a mainframe setup. Possible operating systems that can be used are OS/2 or VMS.

3. Interfacing

3.1 Software Interfacing

ONSPEC 1000 has the capability of being interfaced with Microsoft C, FORTRAN, and Pascal. These languages can be used to create custom reports, applications, and perform calculations on ONSPEC data.

ONSPEC does not currently have a direct interface to SQL relational databases. Although, an interface can be written by the user in one of the languages mentioned above.

3.2 Data Acquisition

ONSPEC can be interfaced directly with both I/O boards, and Programmable Logical Controllers (PLC's) for the purpose of Data Acquisition. The software drivers, required to run these interfaces, are not always written by the software manufacturer. This can cause a number of problems when the interface does not work correctly. For instance, we tested an interface to an Allen-Bradley PLC. The driver that was presented to us, to run the Allen-Bradley PLC, had a couple of bugs. First, it would not allow the computer to complete its boot-up procedure every time the machine was turned on or re-booted. What would happen is as follows: The computer would run through all start up procedures until it got to the section of its boot procedure that required the establishment of communication with the PLC, the computer would establish communication with the PLC, then, on over 60% - 70% of boot attempts, the machine would simply stop functioning and would have to be re-booted to try to start completely again. On average it took 3-4 attempts to boot the machine before it would complete its start-up procedure. If the command to call the PLC drive was removed from the CONFIG.SYS file there was NEVER a problem with booting the machine. The second bug that the driver had was, on occasions, for seemingly no reason, communication with the PLC would stop. Any attempt to restart communications by any other means than re-booting, failed. We called the software manufacturer to try and remedy the situation, since they had not written the driver they had a hard time helping to solve the problem. Two representatives from the company came out to our site to offer a tutorial on ONSPEC. They tried to help us resolve our difficulties with the driver. All attempts to correct the situation did not succeed.

4. Setting up an Application

4.1 The Internal Tables

ONSPEC stores all point values, i.e. inputs, outputs, PID values, etc. in a set of internal tables. There are a number of different types of tables. Some examples of these tables are: Digital Input (DII), Digital Output (DOO), Engineering Units Real (EUR), and Engineering Units Integer (EUI).

4.2 The I/O Template

When an application uses input and output values, from the outside world, i.e. PLC's, sensors, etc..., the first thing that must be done is to create an I/O template. The purpose of this template is to map the physical addresses of these Inputs and Outputs in the computer or PLC, to ONSPEC's internal tables.

4.3 The Display - ONDRAW

The next step in the development process is to draw the sections of a display that are intended to be static, non-moving, using the ONSPEC drawing package, ONDRAW. The drawing package was easy to use and had the capability of drawing most any shape that would be required.

After the static components of a display are drawn, the dynamic sections of a display are then added. These sections are added by using parameters. These parameters are linked to particular table locations. These parameters can be represented symbolically in a display. For instance a digital input parameter can be added and can be displayed on screen as a valve, with

the digital table value used to designate whether the valve is open or closed. These parameters can be added outside of ONDRAW. It is possible to do on-line changes, additions, and deletions to parameters when running the main ONSPEC program.

One feature offered by ONSPEC is object oriented graphics. It is relatively easy to create animation type displays using this feature. To animate a particular set of objects in a display the following is done: (1) All objects to be placed in the animated area are selected. (2) Each individual object is assigned a different animation type feature, i.e. color change, movement, or size change. (3) Beginning and ending locations are assigned to achieve animation. Size changes are achieved by grabbing a corner of the selected object and changing the size of the object to the desired size. The computer takes care of all steps in-between.

There were some problems with the ONDRAW package. For one, it was very hard to change the background color of a display. We tried numerous times to make the background color different than the default blue offered by the system. But many times when the final display was called up, the background would not be the color we selected. The color would be the default blue. Another problem with this drawing package is, sometimes when a parameter was removed from a display, there would still be a residual representation of the parameter. This residual representation was like a shadow of the symbol that had been used to represent the parameter. The only way we found to remove this residual was to re-draw the entire display.

4.4 ONCALC

In order to do on-line internal calculations with ONSPEC it is required to run a spreadsheet program called ONCALC. ONCALC is set up in a typical spreadsheet format,

somewhat like Lotus 1-2-3. With ONCALC, values can be read from and written to ONSPEC's internal tables. All typical arithmetic functions can be performed as well as a number of Boolean type commands.

The ONCALC program was very difficult to understand and work with. The way some of the boolean commands work is very confusing. The documentation provided with ONCALC was poor. It did not clearly explain how to use a number of the functions. To figure out a number of functions, trial and error was the only method we could use.

4.5 Alarming

ONSPEC 1000 has the ability to sound alarms based on the value of any internal table value. The available alarms are: hi limit, low limit, rate of change, and digital change. To use the alarming function the user must first define the desired internal table value to be alarmed as a tag, using the configuration program provided with ONSPEC. After the table location is given a tag name the alarming function, also part of the configuration program, is called up and the desired values are placed in the prompted fields.

The alarming function was very easy to use. One minor annoyance was observed. We could not find the way to turn the audible alarm off. The alarm tends to be distracting when doing development of screens. When the representatives from the software manufacturer came they were unable to figure out how to turn the audible alarm off as well.

4.6 Historical Trending and Statistical Process Control

ONSPEC does come with packages that allow the user to do many functions in the areas

of historical trending and statistical process control. In terms of historical trending, the user is able to chart any desired value over a time period ranging from minutes to weeks. The statistical process control software gives the user access to any desired control chart for any desired internal table value.

We were not able to do an in depth analysis of these features. There were a couple of reasons why we were not able to do this analysis. The first reason is because of time limitations imposed by only having the software for a short amount of time. The second reason was the documentation provided with these packages was poor. When the software manufacturer came to our facility to provide a tutorial session they told us that the best way to test these functions was to read the provided documentation. But, as stated, the documentation fell far short of expectations.

5. Networking

In general, there are three different types of distributed network architecture; Database Duplication, Send/Receive Tables, and Data Transfer Based on Demand. With Database Duplication, an internal database structure is duplicated between all machines on the network. This tends to cause inefficient use of machine memory. The reason for this is that the database structure which is placed on each machine is an "over all" structure. This structure contains all the database pieces required by each machine individually. So there will be some pieces of the database that each individual machine will not need or use. Therefore, there is useless information being stored on each machine and this wastes memory. Also, if the database needs to be updated or revised at all the change must be made to every machine on the network.

Depending on the size of the system this can be quite a tedious task.

Send/Receive tables are tables that tell a software package on an individual machine what information to pick from each machine on the network. One of the primary problems with this is that, generally speaking, it is very difficult to vary these tables. For this reason a system designer must take into consideration which machines might have/need data for future application changes. These potential swaps of data need to be programmed into the tables when the application is first written. Another problem with Send/Receive tables is that the network traffic tends to be very heavy. This is because the data required by these tables is polled off the network each scan period even if the data has not changed.

The basic concept of Data Transfer on Demand is send only the data needed by each machine when it is needed. With this type of architecture each machine has its own internal database that contains information on the data that is needed for which machine. Also, data is only sent on the network when its value changes, minimizing the network traffic. This tends to be the most efficient architecture design.

ONSPEC uses send/receive tables. Each individual machine has a network program running on it that makes sure the current data is gathered in that individual machine. One machine on the network has a special program that oversees all of the actions on the network and acts as a network traffic controller.

6. Examples Tried

6.1 The Tank

In order to test and evaluate ONSPEC two scenarios were tested. The first scenario dealt

with a 100 gallon tank filled with water. The tank had a valve flowing into the tank and a pump flowing out of the tank. When the valve was open, water flowed into the tank at a rate of 1 gallon per second. When the pump was turned on, water flowed out of the tank at a rate of 1 gallon per second. This process was tested using ONCALC. Alarm limits were set as follows:

Low level	-	20 Gallons
OK	-	21-79 Gallons
Hi level	-	80 Gallons

The valves were set such that initially the tank was empty, the valve was open and the pump was off. When the Hi level alarm was set off, the valve closed and the pump turned on, causing the level in the tank to *decrease* by 1 gallon per second. When the Low level alarm was sounded, the valve was opened again and the pump was turned off, causing the level in the tank to *increase* by 1 gallon per second. From here the process started over again.

The display for this example was very easy to do. The main reason for this was that the example provided in the software documentation was very similar to this problem. Therefore, in order to draw the display we followed the instructions provided in the documentation.

The difficulty with this example was figuring out how to do boolean expressions in ONCALC. The explanation provided in the ONCALC manual for these functions was not very clear. After some trial and error we were able to figure out how the expressions worked and were able to set up the correct equations to run the example.

The example provided in the software documentation was actually very good. It was written in a clear manner. It was very helpful in discovering how to use the dynamic symbols,

option, this is the option that allows animation and movement based on the state of the process. It also provided a good introduction to the use of parameters, symbols, alarming, and tags.

6.2 The Saw

To test ONSPEC's ability to interface with a PLC we tried an example using a saw and a clamp. There were four control inputs into the PLC:

- | | | |
|----|----------------------|--|
| 1) | Push Button 0(PB0) - | When this button was pushed the clamp was placed down on a piece of wood and a light pressure (20psi) was applied. |
| 2) | Push Button 1(PB1) - | When this button was pushed a heavier pressure (80psi) was applied to the work piece and the cutting cycle for the saw was initiated. |
| 3) | Increase Speed - | When this button was changed from logical 0 to logical 1 the PLC was programmed to increase the rotary speed of the saw by one (1) unit. |
| 4) | Decrease Speed - | When this button was changed from logical 0 to logical 1 the PLC was programmed to decrease the rotary speed of the saw by one (1) unit. |

This example was more involved than the tank example. The display itself was not that difficult to create. Basically, all that was required for the display was a drawing of the initial set-up. Then, using the dynamic symbol option, the final positions were specified. Anything else that the display needed, i.e. a display of the current value of all system inputs and outputs, was very easy to add.

The difficult part of this example was, again, using ONCALC to program the required control actions. This example needed many If-Then type expressions. The way these If-Then

statements work is difficult to understand. After a long period of trial and error, the ONCALC statements needed to provide the control actions were determined.

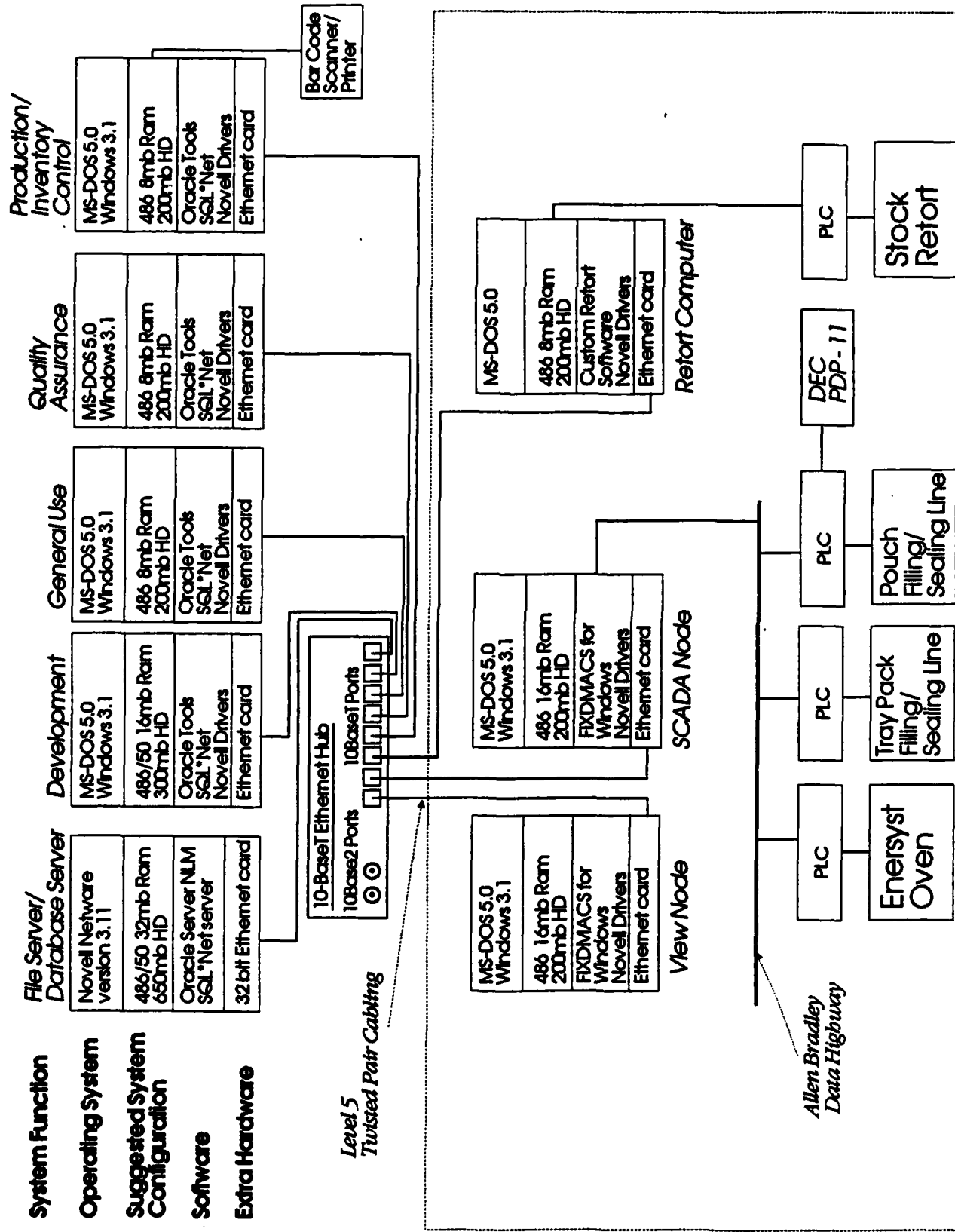
This example illustrated another feature of ONSPEC. That feature is the function key editor. With this option it is possible for the user to program his/her own routines to be executed when a particular function key is pressed. This feature was easy to use. It is also very useful in helping to provide user friendliness.

7. Conclusion

ONSPEC is a fair process control software package. While it is a very powerful package it is not an easy package to learn. The documentation provided with the software is not clear. It is difficult to read and understand. With the exception of one easy example at the back of the tutorial manual, the documentation is severely lacking in clarifying examples. Overall, the quality of the documentation is poor.

With our experience, the technical support offered with this package was not what could be expected. Many times it took longer than expected to get an answer to relatively straightforward problems. The technical staff seemed almost as confused with the software as we did. Overall, the quality of this package is below average.

Recommended CramTD CIM Architecture



Dashed outline is the Shop Floor